TOTAL MAXIMUM DAILY LOAD (TMDL)

for

Fecal Coliform

in

McCrory Creek, Stoners Creek, & Christmas Creek

Located in the

Stones River Watershed (HUC 05130203)
Davidson, Rutherford, & Wilson Counties, Tennessee

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BPJ	Best Professional Judgment
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MWS	Metro Water Services
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
OAP	Overflow Abatement Program
PCS	Permit Compliance System
Rf3	Reach File v.3
RM	River Mile
STP	Sewage Treatment Plant
SWMP	Storm Water Management Plan
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for Fecal Coliform in Stones River Watershed (HUC 05130203)

Impaired Waterbody Information

State: Tennessee
Counties: Cannon, Davidson, Rutherford, & Wilson
Watershed: Stones River (HUC 05130203)
Constituents of Concern: Pathogens

Impaired Waterbodies:

	Waterbody ID	Waterbody	RM
1998 303(d) List	TN05130203001	McCRORY CREEK	12.1
	TN05130203035	STONERS CREEK	3.5
2002 303(d) List	TN05130203001 - 0100	McCRORY CREEK	1.4
	TN05130203018 – 0210	CHRISTMAS CREEK	12.3
	TN05130203035 – 1000	STONERS CREEK	1.9

Designated Uses: The designated use classifications for McCrory Creek, Stoners Creek, and Christmas Creek include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Goal:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, October, 1999* for recreation use classification (most stringent):

> The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

TMDL Development

Analysis/Methodology:

TMDLs for impaired waterbodies in the Stones River watershed were developed using two different methodologies to assure compliance with both the 200 counts/100 ml geometric mean standard and the 1,000 counts/100 ml maximum standards.

Dynamic Loading Model Method

In order to demonstrate compliance with the 200 counts/100 ml geometric mean standard, the Loading Simulation Program C++ (LSPC) was used to simulate the buildup and washoff of fecal coliform bacteria from land surfaces, loading from point sources, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet the target concentrations (standard + MOS) calculated for impaired subwatersheds.

Load Duration Curve Method

A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves were used to determine the load reductions required to meet the target maximum concentration (standard + MOS).

The required load reductions that were determined using each method were compared and the largest load reduction specified as the TMDL for impaired waterbodies.

Expression of TMDLs, WLAs, & LAs:

In this document, fecal coliform TMDLs are expressed as the percent reduction in instream loading required to decrease: a) the existing 30-day geometric mean concentration to the target of 180 counts/100 ml; and b) the existing maximum concentration to the target of 900 counts/100 ml. WLAs & LAs are also expressed as required percent reductions in precipitation induced fecal coliform loading from point sources and nonpoint sources, respectively. WLAs & LAs for non-precipitation induced loading sources are expressed in c fecal coliform counts per period of time.

Seasonal Variation:

The 10-year period used for LSPC model simulation period and for load duration curve analysis included all seasons and a full range of flow and meteorological conditions

Margin of Safety (MOS): Implicit – Conservative modeling assumptions.
Explicit – 10% of the water quality standard for each impaired subwatershed.

TMDLs, WLAs, & LAs

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

Impaired Waterbody	TMDL	WLAs				LAs	
		WWTFs		CAFOs	MS4s	Precipitation Induced Nonpoint Sources	Other Direct Sources
		Monthly Average	Daily Maximum				
	[% Red.]	[cts/day]	[cts/day]	[cts/day]	[% Red.]	[% Red.]	[cts/day]
McCrory Creek	68.8	NA *	NA *	NA	68.8	68.8	0
Stoners Creek	68.9	NA *	NA *	NA	68.9	68.9	0
Christmas Creek	70.2	NA *	NA *	NA	70.2	70.2	0

Notes: NA = Not applicable.
* No permitted discharges from WWTFs in the drainage area. SSOs, which are unpermitted discharges associated with WWTF collection systems, contribute to pathogen impairment are required to be eliminated.

PROPOSED FECAL COLIFORM TOTAL MAXIMUM DAILY LOADS (TMDLs) McCRORY CREEK, STONERS CREEK, & CHRISTMAS CREEK STONES RIVER WATERSHED (HUC 05130203)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not attaining water quality standards. State water quality standards consist of designated use(s) for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for the following three waterbodies in the Stones River Watershed: McCrory Creek, Stoners Creek, and Christmas Creek. Each of these waterbodies has been identified as not supporting designated uses due to pathogens on the 1998 and/or 2002 303(d) list. TMDL development for other pathogen-impaired waterbodies in the Stones River watershed will be addressed in a separate document.

3.0 GENERAL OVERVIEW – STONES RIVER WATERSHED

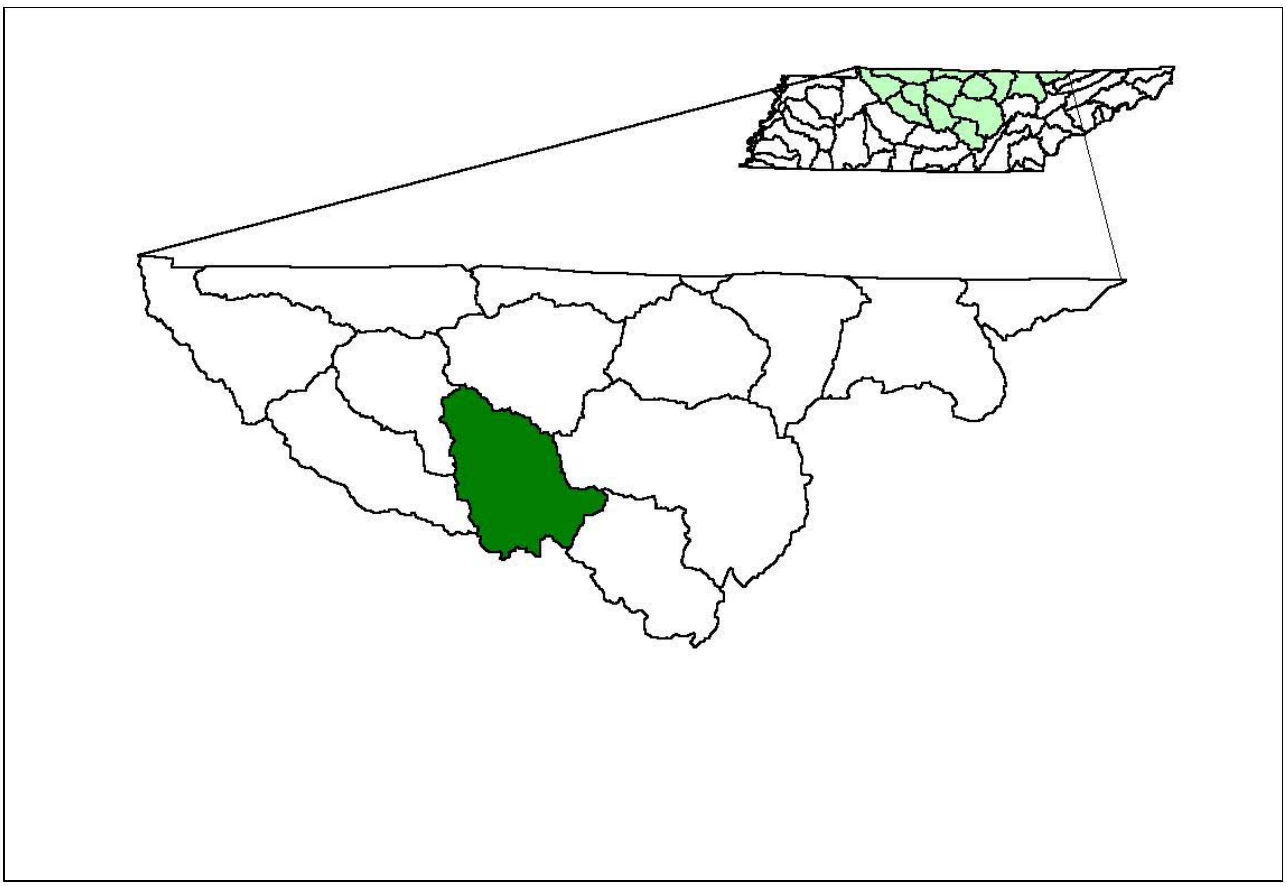
The Stones River watershed (HUC 05130203) is located in Middle Tennessee (Figure 1) and is primarily located in Cannon, Davidson, Rutherford, and Wilson Counties. The watershed lies within the Level III Interior Plateau (71) ecoregion and contains three Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- The Eastern Highland Rim (71g) has level terrain, with landforms characterized as tablelands of moderate relief and irregular plains. Mississippian-age limestone, chert, shale, and dolomite predominate, and karst terrain sinkholes and depressions are especially noticeable between Sparta and McMinnville. Numerous springs and spring-associated fish fauna also typify the region. Natural vegetation for the region is transitional between the oak-hickory type to the west and the mixed mesophytic forests of the Appalachian ecoregions (68, 69) to the east. Bottomland hardwood forest has been inundated by several large impoundments. Barrens and former prairie areas are now mostly oak thickets or pasture and cropland.

- Outer Nashville Basin (71h) is a more heterogeneous region than the Inner Nashville Basin, with more rolling and hilly topography and slightly higher elevations. The region encompasses most all of the outer areas of the generally non-cherty Ordovician limestone bedrock. The higher hills and knobs are capped by the more cherty Mississippian-age formations, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forests with pasture and cropland are the dominant land covers. Streams are low to moderate gradient, with productive nutrient-rich waters, resulting in algae, rooted vegetation, and occasionally high densities of fish. The Nashville Basin as a whole has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.

- Inner Nashville Basin (71i) is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the Inner Basin are a maple-oak-hickory-ash association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest/cedar glades vegetation type with many endemic species, are located primarily on the limestone of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species.

Figure 1 Location of the Stones River Watershed



The Stones River watershed has approximately 1,461 miles of streams (Rf3) and drains a total area of 936 square miles. The mouth of the Stones River is at Cumberland River (Cheatham Lake) mile 205.8. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Land use for the Stones River watershed and McCrory Creek, Stoners Creek, and Christmas Creek drainage areas are summarized in Table 1 and shown in Figure 3.

Figure 2 Level IV Ecoregions in the Stones River Watershed

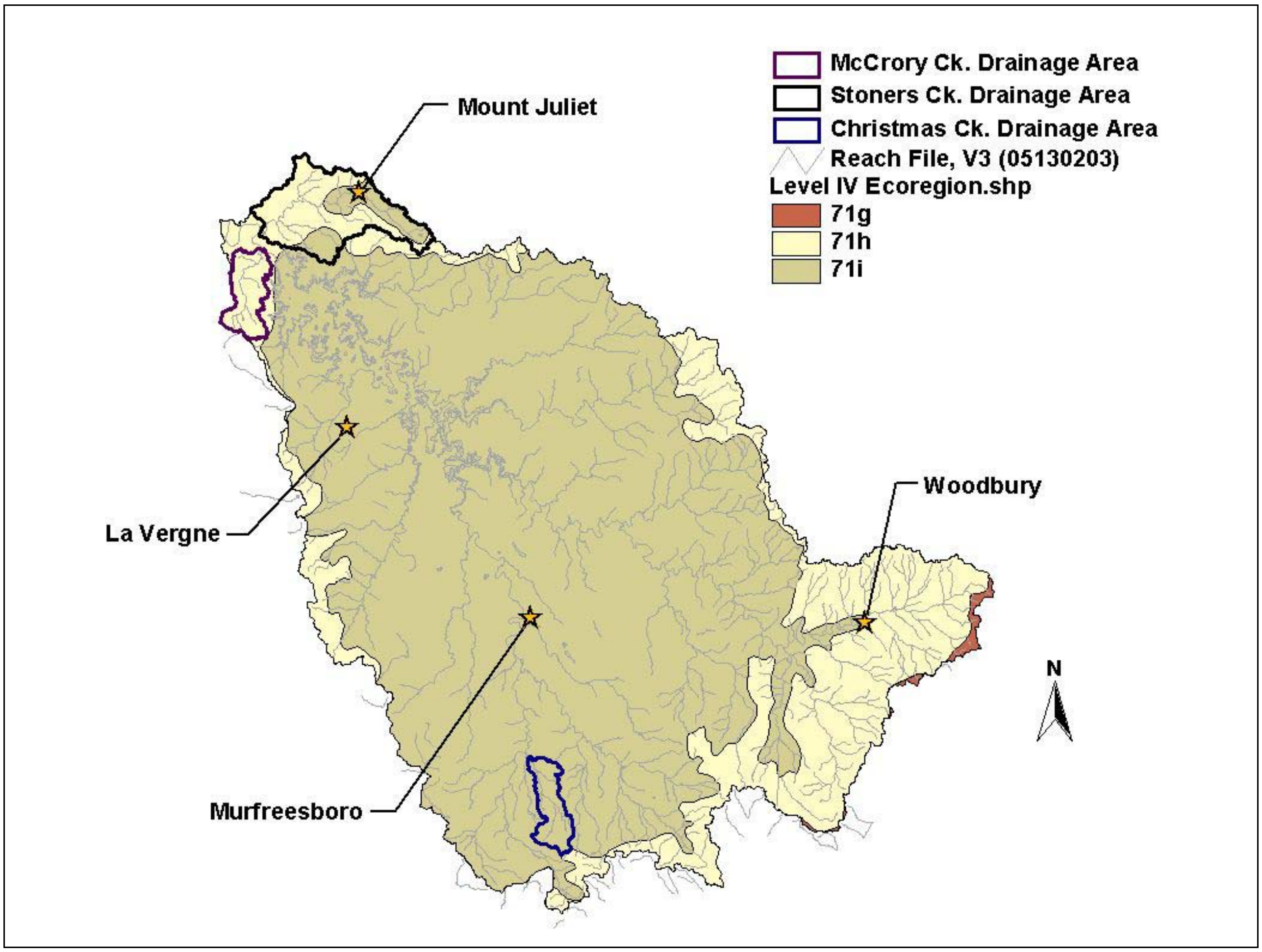


Figure 3 MRLC Land Use Distribution in the Stones River Watershed

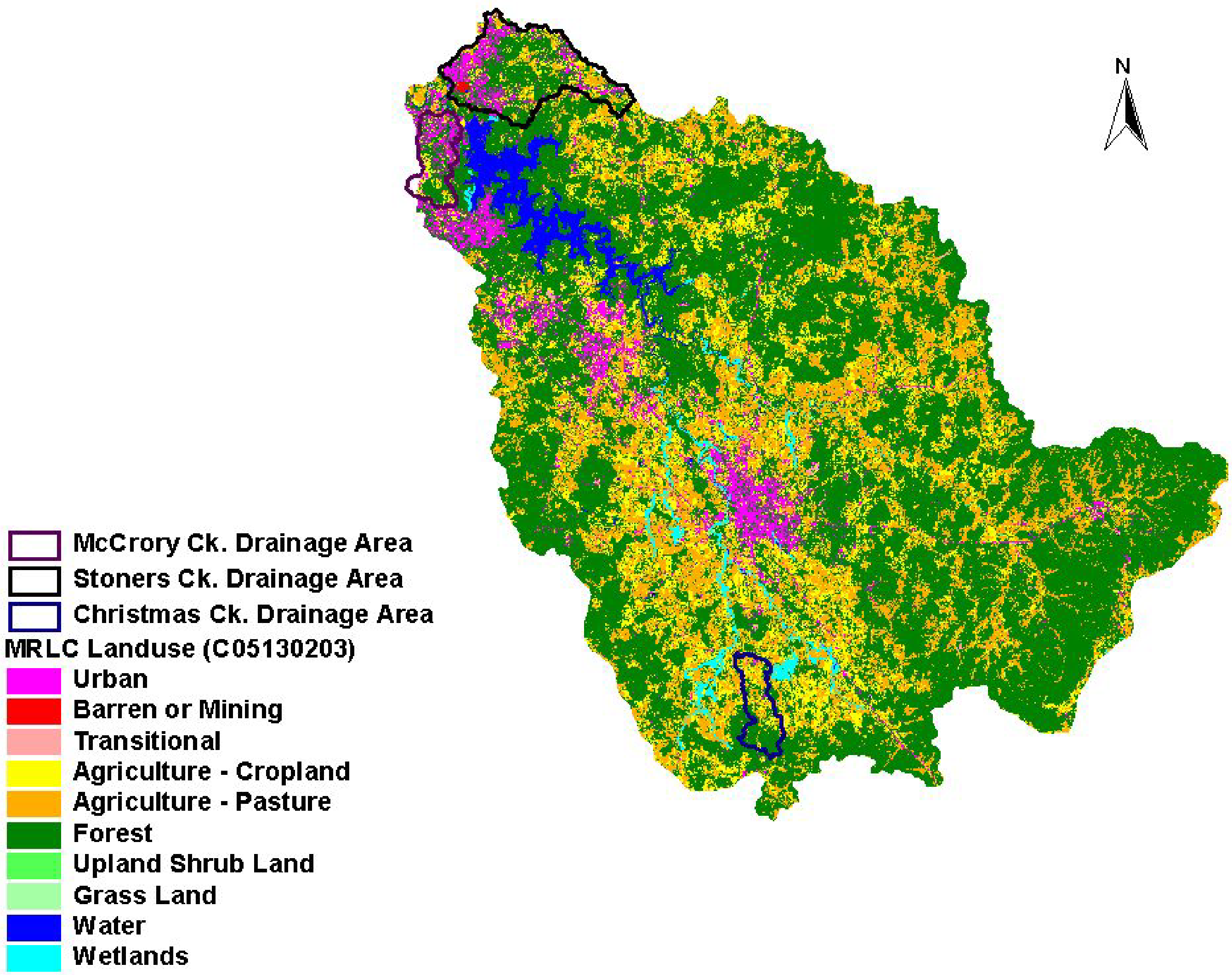


Table 1 MRLC Land Use Distribution – Stones River Watershed & Selected Subwatersheds

Land Use Classification	Drainage Area							
	Watershed Total		McCrory Creek		Stoners Creek		Christmas Creek	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Open Water	14,662	2.45	5	0.09	19	0.10	2	0.04
Low Intensity Residential	17,499	2.92	1,180	20.33	3,088	16.16	76	1.54
High Intensity Residential	3,494	0.58	155	2.67	474	2.48	1	0.02
High Intensity Commercial /Industrial/Transportation	8,570	1.43	532	9.16	639	3.34	28	0.57
Bare Rock/Sand/Clay	3	0.00	0	0.00	0	0.00	0	0.00
Transitional	661	0.11	34	0.59	10	0.05	4	0.08
Deciduous Forest	212,529	35.49	912	15.71	3,859	20.20	1,696	34.26
Evergreen Forest	38,346	6.40	473	8.15	1,188	6.22	155	3.13
Mixed Forest	96,999	16.20	1,285	22.14	4,455	23.32	697	14.08
Pasture/Hay	123,954	20.70	335	5.77	2,655	13.90	1,263	25.52
Row Crops	64,841	10.83	267	4.60	1,380	7.22	955	19.29
Other Grasses (Urban/Recreational)	9,662	1.61	618	10.65	1,141	5.97	64	1.29
Woody Wetlands	6,821	1.14	5	0.09	0	0.00	9	0.18
Emergent Herbaceous Wetlands	661	0.11	4	0.07	0	0.00	0	0.00
Quarries/Strip Mines/Gravel Pits	210	0.04	0	0.00	196	1.03	0	0.00
Total	**598,212**	**100.00**	**5,805**	**100.00**	**19,104**	**100.00**	**4,950**	**100.00**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 1998 303(d) list (TDEC, 1998) was approved by the U.S. Environmental Protection Agency (EPA), Region IV on September 17, 1998. The list identified McCrory Creek and portions of Stoners Creek as not fully supporting designated classifications due, in part, to pathogens (see Table 2). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

When used in the context of waterbody assessments, the term pathogens is defined as disease-causing organisms such as bacteria or viruses that can pose an immediate and serious health threat if ingested or introduced into the body. The main sources for pathogens are untreated or inadequately treated human or animal fecal matter. The fecal coliform group is an indicator of the presence of pathogens in a stream.

Waterbodies in the Stones River watershed were reassessed by the State in 2000 using more recent data and a revised waterbody identification system. This reassessment indicated that Christmas Creek and portions of McCrory Creek and Stoners Creek were not fully supporting designated classifications due, in part, to pathogens. The results of the reassessment represent the best professional judgment (BPJ) of the Division of Water Pollution Control (DWPC) and were incorporated into the 2002 303(d) List (see Table 3), submitted to EPA in September, 2002 (TDEC, 2002). The waterbody listings in Table 3 represent more precisely defined waterbody assessments than those listed in the 1998 303(d) list (ref: Table 2). The last column in Table 3 provides the link between the 2002 assessment and the 1998 303(d) list. The segments of McCrory Creek, Stoners Creek, and Christmas Creek identified as impaired for pathogens on the 1998 or 2002 303(d) list are shown in Figure 4.

A description of the stream assessment process in Tennessee can be found in *2002 305(b) Report, The Status of Water Quality in Tennessee* (TDEC, 2002). The waterbody segments listed in Table 3 were assessed as impaired based on sampling data and/or biological surveys. The results of these assessment surveys are summarized in Table 4. The assessment information presented is excerpted from the EPA/TDEC Assessment Database (ADB) and is referenced to the waterbody IDs in Table 3. ADB information may be accessed at:

http://gwidc.memphis.edu/website/dwpc/

Table 2 1998 303(d) List for Pathogens – McCrory Creek & Stoners Creek

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	CAUSE (Pollutant)	Pollutant Source
TN05130203001	MCCRORY CREEK is not supporting		12.1	Habitat Alteration Pathogens	Urban runoff/storm sewers Collection system failure
TN05130203035	STONERS CREEK- Portion of Stoners Creek and unnamed tributary is partially supporting.	3.5		Siltation Oil and grease Pathogens	Land Development Industrial permitted runoff Spills Collection system failure

Table 3 2002 303(d) List for Pathogens – McCrory Creek, Stoners Creek, & Christmas Creek

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	CAUSE (Pollutant)	Pollutant Source	Reference to 1998 303(d) List Waterbody ID
TN05130203001 – 0100	MCCRORY CREEK	1.4		Other habitat Alterations Pathogens	Collection System Failure Hydromodification	TN05130203001
TN05130203018 – 0210	CHRISTMAS CREEK *		12.3	Siltation Pathogens	Pasture Grazing	
TN05130203035 – 1000	STONERS CREEK	1.9		Siltation Pathogens	Land Development Collection System Failure	TN05130203035

Figure 4 Waterbody Segments on 1998 or 2002 303(d) List for Pathogens – McCrory Creek, Stoners Creek, & Christmas Creek

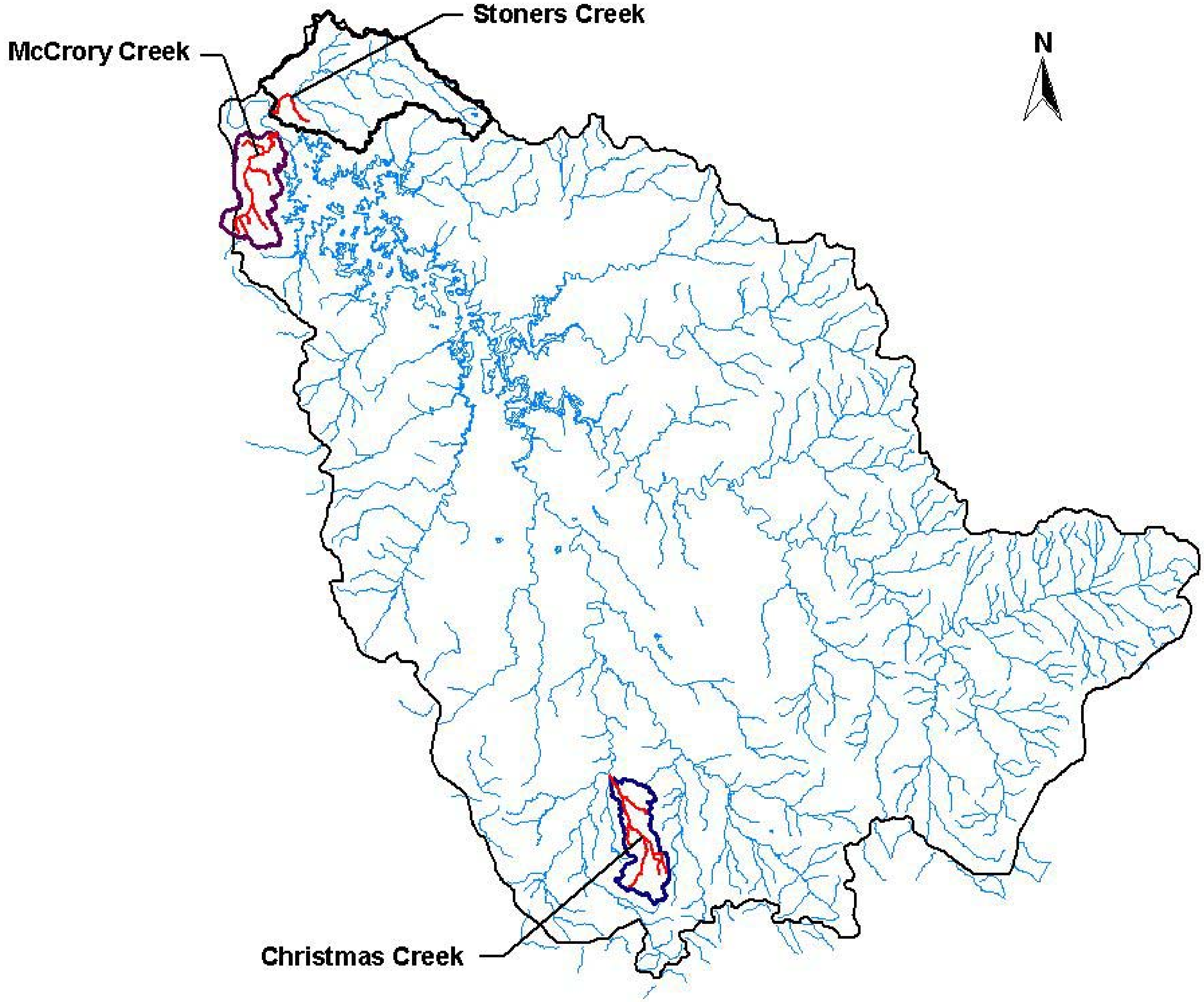


Table 4 Water Quality Assessment of Waterbodies Impaired Due to Pathogens – McCrory Creek, Stoners Creek, & Christmas Creek

Waterbody ID	Segment Name	Cause	Sources	Comments
TN05130203001-0100	McCrory Creek (Stones River to Stewarts Ferry Pike)	Other Habitat Alteration Pathogens	Collection System Failure Hydromodification	Metro pathogen sampling at mile 0.4 and 1.3. Also, bypassing reports from Metro. 1997 TDEC biological survey at mile 1.5. (Stewarts Ferry Pike).
TN05130203018-0210	Christmas Creek (Lytle Creek to headwaters)	Siltation Pathogens	Pasture Grazing	TDEC 2000 probabilistic monitoring station at mile 0.7 at Crescent Road. Violated proposed biocriteria for 71i. One high E. coli observation.
TN05130203035-1000	Stoners Creek (Stones River to unnamed tributary)	Siltation Oil and grease Pathogens	Land Development Industrial permitted runoff Spills Collection system failure	1996 TDEC biological survey at mile 0.8 (Central Pike). 5 EPT families, 22 total families. Habitat score = 153. Bypassing occurs in this segment.

5.0 WATER QUALITY GOAL

As previously stated, the designated use classifications for McCrory Creek, Stoners Creek, and Christmas Creek include Fish & Aquatic Life, Recreation, Irrigation, and Livestock Watering & Wildlife. Of the use classifications with numeric criteria for fecal coliform bacteria, the recreation use classification is the most stringent and will be used as the goal for TMDL development. The fecal coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, October, 1999* (TDEC, 1999). Section 1200-4-3-.03 (4) (f) states:

> The concentration of a fecal coliform group shall not exceed 200 per 100 mL, nor shall the concentration of the *E.coli* group exceed 126 per 100 mL, as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having a fecal coliform group or *E. coli* concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 mL.

The geometric mean standard for fecal coliform of 200 counts/100 ml and the sample maximum of 1,000 counts/100 ml have been selected as the primary instream goals for TMDL development.

Note: In this document, the water quality standard is the instream goal. The term "target concentration" reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 8.3 for an explanation of MOS.

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM GOAL

There are several water quality monitoring stations that provide data for EPA's STORage RETrieval database (STORET) for McCrory Creek, Stoners Creek, and Christmas Creek:

- CHRIS000.7RU – Christmas Creek, 500 yards downstream of Crescent Road (~RM 0.7).
- MCCRO001.5DA – McCrory Creek at Stewart Ferry Pike (~RM 1.5).
- STONE001.1DA – Stoners Creek off Central Pike (~RM 1.1).

The location of these monitoring stations is shown in Figure 5. Water quality monitoring results are tabulated in Table 5. Examination of this data shows violations of the sample maximum fecal coliform standard at all three stations . There was not enough data to determine compliance with the geometric mean standards for fecal coliform or *E. coli*.

Figure 5 Water Quality Monitoring Stations – McCrory Creek, Stoners Creek, & Christmas Creek

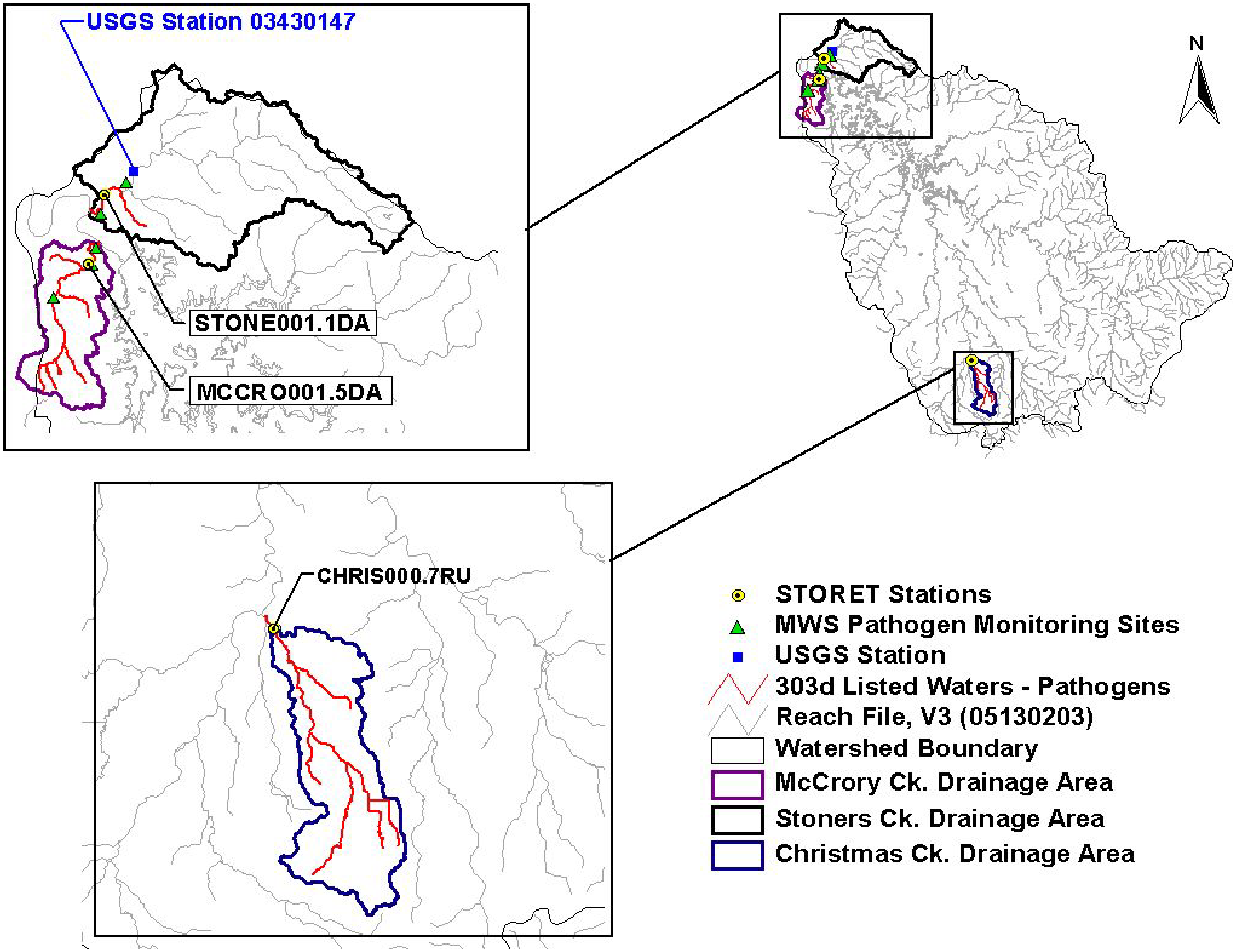


Table 5 Water Quality Monitoring Data for Impaired Waterbodies

Station ID	Date	Time	Fecal Coliform	E. coli	Flow
			[cts./100 ml]	[cts./100 ml]	[cfs]
CHRIS000.7RU	1/11/00	1200	420	650	6.16
	4/12/00	0957	<1	<1	
	4/12/00	1147	2,100 *	>2,400	36.38
	4/12/00	1157	1,500	2,000	
	4/21/00	1310	<1	<1	
	7/26/00	0703	<1	<1	
	7/26/00	1053	110	99	
	7/26/00	1058	170	120	
	7/26/00	1126	<1	<1	
	10/19/00	0655	<1	<1	
	10/19/00	0820	<1	<1	
	10/19/00	0915	2,400	2,000	
	10/19/00	0920	3,800	2,400	
	5/2/01	1240	260	370	0.296
MCCRO001.5DA	10/24/01	1400	270	100	2.08
	11/15/01	1245	120	63	0.64
	12/6/01	1220	900	230	6.20
	1/24/02	1130	4,000	2,100	
	3/26/02	1120	3,100	2,000	45
	4/23/02	1250	400	490	3.95
	5/16/02	1236	500	550	11.56
	6/19/02	1150	800	820	0.70
STONE001.1DA	10/24/01	1435	1,200	370	
	11/15/01	1335	19 *	83	2.08
	12/6/01	1250	1,100	250	15.40
	1/24/02	1150	7,500 *	8,000	
	3/26/02	1155	5,800	>2,400	
	4/23/02	1330	170	170	2.47
	5/16/02	1321	300	290	58
	6/19/02	1225	210	250	0.23

* Estimated.

As part of its Overflow Abatement Program, the Metro Nashville/Davidson County Department of Water and Sewerage Services (MWS) conducted both dry and wet weather monitoring in McCrory Creek and Stoners Creek in 1996 to determine major sources of fecal coliform bacteria in these waterbodies and to recommend further actions to improve water quality. This monitoring was conducted by Consoer Townsend Envirodyne Engineers, Inc. (CTEE) on behalf of MWS, at a number of locations in McCrory Creek and Stoners Creek. Monitoring results are tabulated in Tables A-1 through A-4 in Appendix A. Examination of the dry weather data shows no violations of instream water quality criteria. Wet weather data, collected on 9/26/96, exceeded the 1,000 counts/100 ml maximum criteria at two locations in both McCrory Creek and Stoners Creek.

MWS also conducted pathogen monitoring in McCrory Creek and Stoners Creek at various times during the period from 1999 through 2003. This sampling was performed to support recommendations to the Division of Water Pollution Control (DWPC) regarding the 303(d) status of these waterbodies. The results of this monitoring are summarized in Appendix A, Tables A-5, A-6, & A-7. There was one exceedance of the maximum fecal coliform criteria in Stoners Creek (2,890 cts/100 ml on 8/10/00) and one exceedance of the 30-day geometric mean criteria in McCrory Creek (260 cts/100 ml from 5/31/00 through 6/13/00). All other data were below the applicable standards.

7.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of fecal coliform bacteria in the watershed and the amount of pollutant loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by three broad subcategories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain fecal coliform bacteria. There are 16 NPDES permitted WWTFs in the Stones River watershed that discharge treated sanitary wastewater. These facilities are tabulated in Table 6 and the location shown in Figure 6. It should be noted that none of these WWTFs are authorized to discharge directly to the McCrory Creek, Stoners Creek, or Christmas Creek drainage areas.

Figure 6   NPDES Permitted Wastewater Treatment Facilities & CAFOs

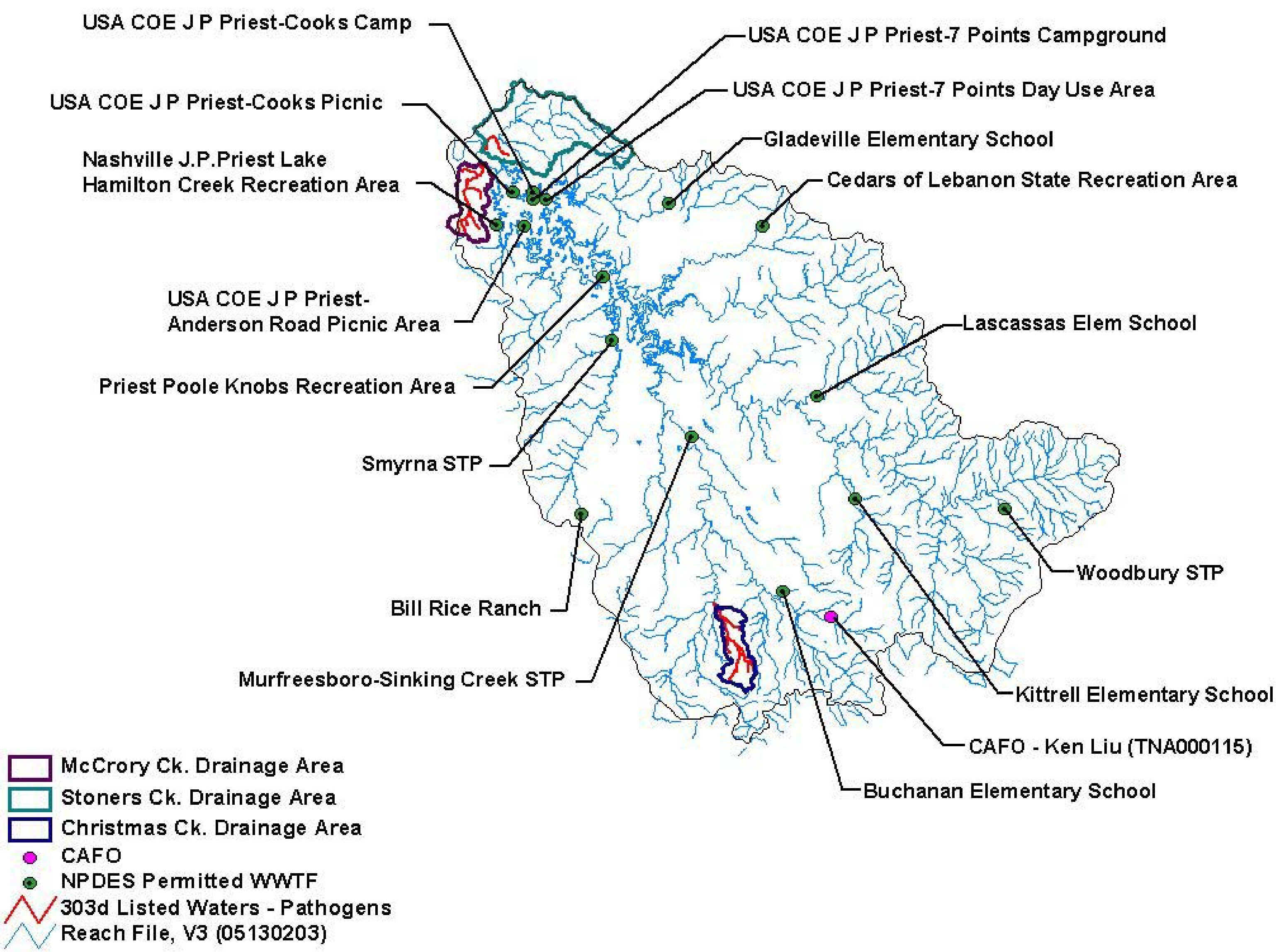


Table 6 WWTFs Permitted to Discharge Treated Sanitary Wastewater in the Stones River Watershed

NPDES Permit No.	Facility Name	Receiving Stream
TN0020541	Smyrna STP	Stewart Creek
TN0021458	COE J.P. Priest – Anderson Road Picnic Area	Smith Spring Creek
TN0021474	COE J.P. Priest – Cooks Picnic Area	Stones River
TN0021482	COE J.P. Priest – Cooks Camp	Stones River
TN0022586	Murfreesboro Sinking Creek STP	West Fork Stones River
TN0024325	Priest Poole Knobs Recreation Area	J.P. Priest Lake (Stones River)
TN0025089	Woodbury STP	East Fork Stones River
TN0028550	J.P. Priest Lake – Hamilton Creek Recreation Area	J.P. Priest Lake (Hamilton Creek)
TN0028568	COE J.P. Priest – 7 Points Day Use Area	Suggs Creek
TN0029319	COE J.P. Priest – 7 Points Campground	Suggs Creek
TN0057797	Buchanan Elementary School	Unnamed tributary to Middle Fork Stones River
TN0057801	Gladeville Elementary School	Unnamed tributary of unnamed tributary to Suggs Creek
TN0057975	Bill Rice Ranch	Unnamed tributary to Stewart Creek
TN0058149	Cedars of Lebanon State recreation Area	Cave Creek
TN0067245	Lascassas Elementary School	Bradley Creek
TN0067253	Kittrell Elementary School	Cripple Creek

Non-permitted point sources of pathogen contamination of surface waters associated with STP collection systems include leaking collection systems and sanitary sewer overflows (SSOs). As stated in the *McCrory Creek Pollutant Source Study* (MWS, 1998):

> Many of the streams historically have sewer problems within their watershed boundaries. The result is wet weather related sanitary sewer overflows (SSOs), which may be significant sources of fecal contamination. Part of the original Commissioner's Order of 1990 required significant sewer line improvements in the separated sewer system areas. This was an action to reduce the SSOs from the separate sewer system. These documented overflows typically occur along Metro's large trunk sewers which parallel many of the tributaries to the Cumberland River. During rain events, rain water infiltrates into the sanitary sewers via loose seals, sewer line cracks, illegal storm drain connections, etc. Lines become surcharged and overflow at low points. In a gravity system these lines are typically located adjacent to the stream.

The Tennessee Department of Environment and Conservation (TDEC) issued Commissioners Order #88-3364 to Metro on March 30, 1990. This order required Metro to improve their sewage collection and treatment system in order to limit the frequency and impact of Combined Sewer Overflows (CSOs) to the Cumberland River and essentially eliminate SSOs within smaller tributary watersheds. Metro's Overflow Abatement Program (OAP), managed by CTEE, was created to address the issues raised in this order. A second Commissioner's Order (99-0390), issued on September 17, 1999 extended the timeframe for full compliance with the 1990 order. Since its inception, according to the OAP website (www.nashvilleoap.com), 96 of the most critical overflow points in the sanitary sewer system have been eliminated. Active SSOs, however, are still listed for McCrory Creek (#103, McCrory Creek pumping station) and Stoners Creek (#176 Dodson Chapel pumping station). These active SSOs are considered to be primary causes of fecal coliform loading in the impaired segments of McCrory and Stoners Creek.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of pathogens. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Large and medium MS4s serving populations greater than 100,000 people are required to obtain an NPDES storm water permit. At present, the Metro Nashville/Davidson County is the only MS4 of this size in the Stones River watershed that is regulated by the NPDES program (TNS068047). As of March 2003, small MS4s serving urbanized areas, or having the potential to exceed instream water quality standards, are required to obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2002a). An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of at 1,000 people per square mile. Mount Juliet and Wilson County are covered under Phase II of the NPDES Storm Water Program and are partially located within the Stoners Creek drainage area. The Tennessee Department of Transportation (TDOT) is also being issued MS4 permits for State roads in urban areas. Information regarding storm water permitting in Tennessee may be obtained from the TDEC website at http://www.state.tn.us/environment/wpc/stormh2o/ .

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*, while larger, Class I CAFOs are required to obtain an individual NPDES permit. Requirements of both the general and individual CAFO permits include:

- Development of a Nutrient Management Plan (NMP), and approval of the NMP by the Tennessee Department of Agriculture (TDA).

- Liquid waste handling systems, if utilized, be designed, constructed, and operated to contain all process generated waste waters plus the runoff from a 25-year, 24-hour rainfall event. A discharge from a liquid waste handling facility to waters of the state during a chronic or catastrophic rainfall event, or as a result of an unpermitted discharge, upset, or bypass of the system, shall not cause or contribute to an exceedance of Tennessee water quality standards.

- Other Best Management Practices (BMPs).

As of May 19, 2003, there is only one Class II CAFO in the Stones River watershed with coverage under the general NPDES permit. The location of this facility is shown in Figure 6. It should be noted that this facility is not located in a drainage area of a waterbody identified as impaired for pathogens. There are no CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

Nonpoint sources of fecal coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of pathogen loading are primarily associated with agricultural and urban land uses. On the 1998 and 2002 303(d) lists, the sources of pollution in McCrory Creek and Stoners Creek are attributed to nonpoint urban sources. The source of pollution for Christmas Creek, however, is attributed to nonpoint agricultural sources.

7.2.1 Wildlife

Wildlife deposit fecal coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes. Fecal coliform loads due to deer are estimated by EPA to be 5.0×10^8 counts/animal/day.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of fecal coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing fecal coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.

- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of fecal bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural resources Conservation Service (NRCS).

- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of fecal loading directly to a stream.

Livestock data for pathogen-impaired subwatersheds were compiled from the 1997 Census of Agriculture utilizing the Watershed Characterization System (WCS) and summarized in Table 7. WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development.

Table 7 Estimates of Livestock Population in the McCrory Creek, Stoners Creek, & Christmas Creek Drainage Areas

Livestock	Drainage Area		
	McCrory Ck.	Stoners Ck.	Christmas Ck.
Cattle	248	1,668	276
Beef Cattle		540	577
Dairy Cattle		30	36
Swine	2	39	14
Poultry	1	3	1
Sheep		9	6

7.2.3 Failing Septic Systems

Some fecal coliform loading in the Stones River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in pathogen-impaired subwatersheds utilizing septic systems were compiled using WCS and are summarized in Table 8. In middle Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of fecal bacteria directly to waterbodies.

Table 8 Estimate of Population on Septic Systems in Pathogen Impaired Subwatersheds

Impaired Waterbody	Population on Septic Systems
McCrory Creek	633
Stoners Creek	5,426
Christmas Creek	749

7.2.4 Urban Development

Nonpoint source loading of fecal bacteria from urban land use areas is attributable to multiple sources. These include: storm water runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without infiltration through the soil and interaction with groundwater. The drainage areas for Stoners Creek & McCrory Creek have the largest percentage of urban land use (see Table C-1 and Figures 7 & 8).

Figure 7 Land Use Percentage of Impaired Subwatersheds

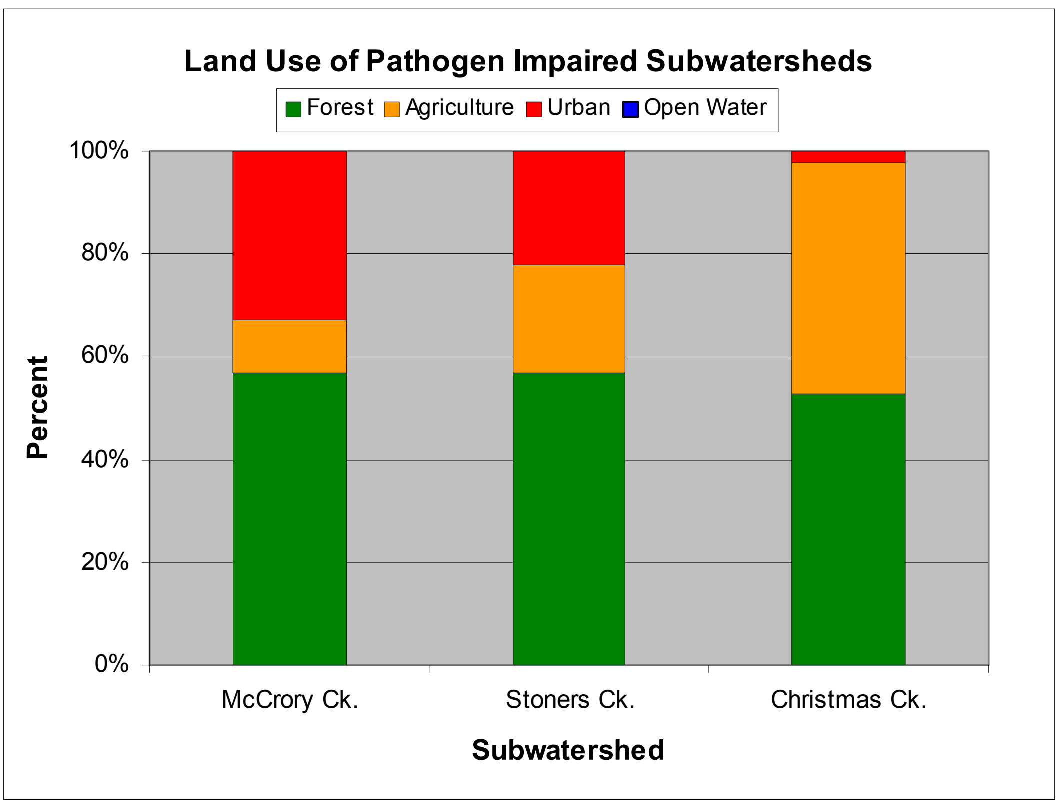
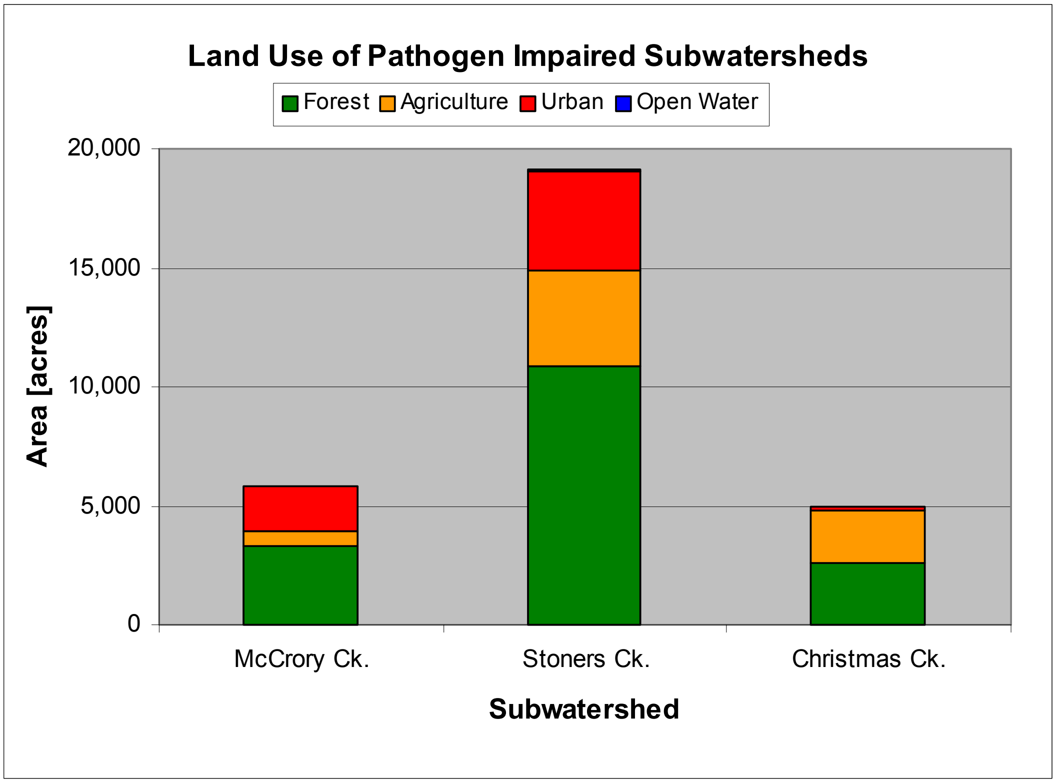


Figure 8 Land Use Area of Impaired Subwatersheds



8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

An important objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or <u>other appropriate measure</u>.

8.1 TMDL Analysis Methodology

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. TMDLs for impaired waterbodies in the Stones River watershed were developed using two different methodologies to assure compliance with both the 200 counts/100 ml geometric mean standard and the 1,000 counts/100 ml maximum standards (ref.: Section 5.0).

8.1.1 Dynamic Loading Model Method

In order to demonstrate compliance with the 200 counts/100 ml geometric mean standard, a dynamic loading model was chosen to: a) continuously simulate fecal coliform bacteria deposition on land surfaces and pollutant transport to receiving waters in response to storm events; b) incorporate seasonal effects on the production and fate of fecal coliform bacteria; and c) simulate continuous fecal coliform concentration in surface waters.

The Loading Simulation Program C++ (LSPC) is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF) and was selected for TMDL analyses of pathogen impaired waters in the Stones River watershed. LSPC was used to simulate the deposition and transport of fecal coliform bacteria from land surfaces, point source loading, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet the target concentrations (standard + MOS) calculated. Details of model development, calibration and TMDL analyses are presented in Appendix B

8.1.2 Load Duration Curve Method

A load duration curve is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves were considered to be well suited for analysis of periodic monitoring data collected by grab sample and determination of the load reductions required to meet the target maximum concentration (standard - MOS). Details of load duration curve development for impaired waterbodies in the Stones River watershed are presented in Appendix C.

8.2 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. In these TMDLs, both and explicit and implicit MOS were utilized.

<u>Dynamic Loading Model Analysis</u>
An explicit MOS, equal to 10% of the geometric mean fecal coliform standard (200 counts/100 ml), was utilized for TMDL modeling analyses. Application of this explicit MOS of 20 counts/100 ml results in an effective 30-day geometric mean target concentration of 180 counts/100 ml.

The implicit MOS includes the use of conservative modeling assumptions and a 11-year continuous simulation that incorporates a range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; all land uses connected directly to streams; and a conservative value was used to estimate the in-stream decay of fecal coliform in the waterbodies.

Load Duration Curve Analysis
An explicit MOS, equal to 10% of the maximum fecal coliform standard (1,000 counts/100 ml), was utilized for TMDL analyses. Application of this explicit MOS of 100 counts/100 ml results in an effective maximum target concentration of 900 counts/100 ml.

Note: In this document, the water quality standard is the instream goal. The term "target concentration" reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 5.0.

8.3 Expression of TMDL, WLAs, & LAs

In this document, fecal coliform TMDLs are expressed as the percent reduction in instream loading required to decrease: a) the existing 30-day geometric mean concentration to the target of 180 counts/100 ml; and b) the existing maximum concentration to the target of 900 counts/100 ml. WLAs & LAs are also expressed as required percent reductions in precipitation induced fecal coliform loading from point sources and nonpoint sources, respectively. Allocations for loading that are independent of precipitation (WLAS for WWTFs, WLAs for CAFOs, and LAs for "other direct sources") are expressed as counts per day.

8.4 Determination of TMDLs

Load reductions for McCrory Creek, Stoners Creek, and Christmas Creek were developed using the Dynamic Loading Model to achieve compliance with the 30-day geometric mean target concentration (Appendix B). Load reductions were also developed for these waterbodies using Load Duration Curves to achieve compliance with the maximum target concentration (Appendix C). The instream load reductions associated with these determined by these two methodologies were compared and the largest required load reduction was selected as the TMDL for each impaired stream. TMDLs for impaired waterbodies are shown in Table 9.

Table 9 Determination of TMDLs for Impaired Waterbodies

Impaired Waterbody	Required Load Reduction		
	Dynamic Loading Model [a]	Load Duration Curve [b]	TMDL
	[%]	[%]	[%]
McCrory Creek	68.8	51.3	68.8
Stoners Creek	NR	68.9	68.9
Christmas Creek	55.0	70.2	70.2

Notes: NR = No reduction required.
a. Required load reduction to comply with 30-day geometric mean target of 180 cts./100 ml (Standard – MOS).
b. Required load reduction to comply with maximum target of 900 cts./100 ml (Standard – MOS).

8.5 Determination of WLAs & LAs

WLAs & LAs are expressed as required percent reductions in fecal coliform loading and as developed in Appendix D. TMDLs, WLAs, & LAs for impaired waterbodies are summarized in Table 10.

Table 10 Summary of TMDLs, WLAs, & LAs for McCrory Creek, Stoners Creek, & Christmas Creek

Impaired Waterbody	TMDL	WLAs				LAs	
		WWTFs		CAFOs	MS4s	Precipitation Induced Nonpoint Sources	Other Direct Sources
		Monthly Average	Daily Maximum				
	[% Red.]	[cts/day]	[cts/day]	[cts/day]	[% Red.]	[% Red.]	[cts/day]
McCrory Creek	68.8	NA *	NA *	NA	68.8	68.8	0
Stoners Creek	68.9	NA *	NA *	NA	68.9	68.9	0
Christmas Creek	70.2	NA	NA	NA	70.2	70.2	0

Notes: NA = Not applicable.

* No permitted discharges from WWTFs in the drainage area. SSOs, which are unpermitted discharges associated with WWTF collection systems, contribute to pathogen impairment are required to be eliminated.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waters in the Stones River watershed through reduction of excessive pathogen loading. An adaptive management approach, within the context of the State's rotating watershed management approach, will be used to refine TMDLs, WLAs, and LAs as required to meet water quality goals.

9.1 Waste Load Allocations for Point Sources

9.1.1 NPDES Regulated Wastewater Treatment Facilities

At present, there are no permitted discharges from WWTFs in the McCrory Creek, Stoners, Creek, or Christmas Creek drainage areas. Future discharges of treated sanitary wastewater from industrial and municipal wastewater treatment facilities will be required to be in compliance with water quality standards (ref: Section 5.0) for pathogens prior to discharge.

The SSOs in the McCrory Creek and Stoners Creek drainage areas are unpermitted discharges and are required to be eliminated. As stated in Section 7.1.1, the Metro Nashville/Davidson County Overflow Abatement Program was created, in response to a Commissioner's Order, to eliminate CSOs to the Cumberland River and SSOs to tributary watersheds, including McCrory Creek and Stoners Creek. According to the OAP website (www.nashvilleoap.com), 96 of the most critical overflow points in the sanitary sewer system have been eliminated since the program's inception. However, 35 SSOs are still active, including one each to McCrory Creek and Stoners Creek. Continued compliance with Commissioner's Orders will result in the elimination of SSOs within a reasonable time frame.

9.1.2 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

At the present time, there are no CAFOs located in the McCrory Creek, Stoners, Creek, or Christmas Creek drainage areas.

9.1.3 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For regulated discharges from municipal separate storm sewer systems in the McCrory Creek, Stoners, Creek, or Christmas Creek drainage areas, WLAs will be implemented through Phase I & II MS4 permits.

<u>Phase I Permit</u>
NPDES Permit No. TNS068047, a Phase I MS4 permit issued to Metro Nashville/Davidson County, specifies a number of activities to be performed as part of its Storm Water Management Program (SWMP) in several program areas:

- Structural storm water controls and collection systems
- New development and significant redevelopment
- Roadways

- Landfills and other waste treatment, storage, or disposal facilities
- Pesticides, herbicides, fertilizers, oils, and other toxic materials
- Illicit discharges and improper disposal
- Industrial and high risk runoff
- Construction site runoff
- Habitat improvement
- Public information and education
- Reporting

In addition, the permit requires that the permittee must reduce the discharge of pollutants to the "maximum extent practicable", not cause or contribute to violations of State water quality standards, annually report how the SWMP will control the discharge of pollutants of concern to impaired waterbodies, and evaluate if existing storm water control measures are adequate to comply with any TMDL requirements.

Phase II Permits
Smaller MS4s, such as Mount Juliet and Wilson County, are covered under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2002a). This permit requires the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. The permit was issued on February 27, 2003 and requires SWMPs to include six minimum control measures:

- Public education and outreach on storm water impacts
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site storm water runoff control
- Post-construction storm water management in new development and re-development
- Pollution prevention/good housekeeping for municipal operations

For discharges into impaired waters, the Small MS4 General Permit (ref: http://www.state.tn.us/environment/wpc/stormh2o/MS4II.shtml) also requires that SWMPs include a section describing how discharges of pollutants of concern will be controlled to ensure that they do not cause or contribute to instream exceedances of water quality standards. Specific measures and BMPs to control pollutants of concern must also be identified. In addition, MS4s must implement the WLA provisions of an applicable TMDL and describe methods to evaluate whether storm water controls are adequate to meet the WLA.

Implementation of the fecal coliform WLAs for MS4s in this TMDL document will require effluent or instream monitoring to evaluate SWMP effectiveness with respect to reduction of pathogen loading.

9.2 Load Allocations for Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of pathogen loading from nonpoint sources (NPS) will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and nongovernmental levels to be successful.

The Tennessee Department of Environment & Conservation (TDEC) will coordinate with the Tennessee Department of Agriculture (TDA) and the Natural Resources Conservation Service (NRCS) to address issues concerning fecal coliform loading from agricultural land uses in the Stones River watershed. It is recommended that additional information (such as livestock populations by subwatershed, animal access to streams, manure application practices, etc.) be evaluated to better identify and quantify agricultural sources of fecal coliform loading in order to reduce uncertainty in future modeling efforts. It is further recommended that BMPs be utilized to minimize the amount of fecal coliform bacteria transported to surface waters from agricultural sources.

9.3 Source Identification

An important aspect of pathogen load reduction activities is the accurate identification of the actual sources of pollution. In many cases, the sources of elevated fecal coliform concentrations in impaired waterbodies are not readily apparent. At the present time, Bacteria Source Tracking (BST) activities are underway or planned in the Stones River watershed.

<u>McCrory Creek and Stoners Creek Project</u>

A project, involving investigators from Vanderbilt University, Consoer-Townsend-Envirodyne Engineers, Inc., and MWS, is in progress to identify pathogen bacteria sources in McCrory Creek and Stoners Creek utilizing antibacterial resistance analysis (ARA) methods. Preliminary results from this project are summarized in a paper entitled: *Sampling and Analysis of McCrory and Stoners Creeks, 2000-2003* (Hamilton, 2003), which is reproduced in Appendix E.

Stones River Watershed Project

A BST project, led by Dr. Frank Bailey of Middle Tennessee State University, is planned for a number of locations in the Stones River watershed. This project is partially funded through a 319 grant.

9.4 Evaluation of TMDL Effectiveness

The effectiveness of the TMDL will be assessed within the context of the State's rotating watershed management approach. Watershed monitoring and assessment activities will provide information by which the effectiveness of pathogen loading reduction measures can be evaluated. Additional monitoring data (including *E. coli* data to evaluate compliance with *E. coli* criteria)), ground-truthing activities, and bacterial source identification actions are recommended to enable implementation of particular types of BMPs to be directed to specific areas in impaired subwatersheds. This will optimize utilization of resources to achieve maximum reductions in pathogen loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure attainment of applicable water quality standards.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed fecal coliform TMDLs for the Stones River watershed were placed on Public Notice for a 46-day period on May 8, 2004 and comments solicited. Steps that taken in this regard included:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website on March 8, 2004. The announcement invited public and stakeholder comment until April 12, 2004 and provided a link to a downloadable version of the TMDL document. The comment period was extended 10 days as noted in #5 below.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) A draft copy of the proposed TMDLs was sent to Metro Nashville/Davidson County, City of Mount Juliet, Wilson County, and the Tennessee Department of Transportation.

4) A letter was sent to point source facilities in the Stones River study area that are permitted to discharge treated sanitary wastewater advising them of the proposed fecal coliform TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided on request. Letters were sent to the following facilities:

   Woodbury STP (TN0025089)
   Kittrell Elementary School (TN0067253)
   Lascassas Elementary School (TN0067245)

Buchanan Elementary School (TN0057797)
Murfreesboro Sinking Creek STP (TN0022586)
Gladeville Elementary School (TN0057801)
Cedars of Lebanon State Park (TN0058149)
Smyrna STP (TN0020541)
COE J.P. Priest – Anderson Road Picnic Area TN0021458)
COE J.P. Priest – Cooks Picnic Area (TN0021474)
COE J.P. Priest – Cooks Camp (TN0021482)
Priest Poole Knobs Recreation Area (TN0024325)
J.P. Priest Lake – Hamilton Creek Recreation Area (TN0028550)
COE J.P. Priest – 7 Points Day Use Area (TN0028568)
COE J.P. Priest – 7 Points Campground (TN0029319)
Bill Rice Ranch (TN0057975)
Nashville Central STP (TN0020575)

5) A meeting was held on March 12, 2004 with representatives of Metro Waters Systems and their consultants to present information on the TMDL program generally and the fecal coliform TMDLs for Stoners Creek, McCrory Creek, and Christmas Creek. At this meeting, several typographical errors were brought to the attention of the DWPC. These errors were corrected in the TMDL document on March 15 and the comment period extended 10 additional days. Letters were sent to a number of stakeholders advising them of the corrected document and the extended comment period.

Written comments were received from stakeholder during the public comment period. These comments are included in Appendix G and the Division of Water Pollution Control responses are contained in Appendix H. No requests to hold additional public meetings were received regarding the proposed TMDLs as of close of business on April 22, 2004.

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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APPENDIX A

Summary of Results – Overflow Abatement Program Monitoring

As part of its Overflow Abatement Program, the Metro Nashville/Davidson County Department of Water and Sewerage Services (MWS) conducted both dry and wet weather monitoring of McCrory Creek and Stoners Creek in 1996 to determine major sources of fecal coliform bacteria in these waterbodies and to recommend further actions to improve water quality. This monitoring, conducted by Consoer Townsend Envirodyne Engineers, Inc. (CTEE) on behalf of MWS, is summarized in Tables A-1 & A-2 (MWS, 1998) for McCrory Creek and Tables A-3 & A-4 (MWS, 1998a) for Stoners Creek.

Table A-1 1996 Dry Weather Survey Data – McCrory Creek

Waterbody	Location	RM	Date	Fecal Coliform [col./100 ml]
McCrory Creek	Elevated sewer crossing	0.2	4/3/96	29
	Above backwater	0.5	4/3/96	78
	Wooded area	0.8	4/3/96	58
	Force main crossing	1.4	4/3/96	72
	d/s Stewarts Ferry Pike	1.4	4/3/96	121
	d/s Stewarts Ferry Pike	1.5	4/3/96	114
	Near Thruxton Court	1.9	4/3/96	53
	d/s Intersection of Boulder Park Drive & Laurel Forest Drive	2.3	4/3/96	33
	Ironwood Drive	2.5	4/3/96	21
	d/s Lakeland Drive	2.7	4/3/96	38
	Boulder Park Road	3.0	4/3/96	13
	u/s Elm Hill Branch	3.2	4/4/96	29
	d/s Elm Hill Pike	3.4	4/4/96	16
	u/s Elm Hill Pike	3.5	4/4/96	100
Trib.-Pump Sta. Br. (RM 0.1)	d/s of manhole #2, u/s of Pumping Sta.	0.1	4/3/96	44
Trib. (RM 0.82)	Underground stream – low flow	0	4/4/96	20
Trib. (RM 1.14)	Near confluence	0	4/4/96	100
	u/s McCrory Creek Road	0.2	4/4/96	53
	Neil Worth Lane	0.5	4/4/96	55
	u/s Interstate 40	0.7	4/4/96	57
Trib. (RM 1.65)	Near McCrory Creek Road	0	4/3/96	37
Trib.-Lakehead (RM 1.82)	d/s Lakeland Drive	0	4/3/96	94
	u/s Cloverwood Drive	0.2	4/4/96	39
Trib.-Ellen Br. (RM 2.69)	At confluence	0	4/3/96	42
Trib.-Hart Br. (RM 3.18)	At confluence	0	4/4/96	6
Trib. (RM 3.3)	Near Hurt Drive, small spring	0	4/4/96	7

Table A-2 1996 Wet Weather Monitoring Results – McCrory Creek

Date	Location	RM	Time	Fecal Coliform col./100 ml	Observations
9/21/96	Mouth	0.0	0653	100	Light rain, 0.6 ft. deep
		0.0	0830	900	Mod. rain, 0.6 ft. deep
		0.0	1011	3,500	Light rain, 1.2 ft. deep
		0.0	1300	5,500	Light rain, 1.8 ft. deep
		0.0	1442	5,900	Light rain, flow receding
		0.0	1605	3,900	No rain, ~ 0.9 ft. deep
	McCrory Creek Road	4.5	0803	4,500	Moderate to light rain
		4.5	0943	1,000	Mod. rain, flow rising
		4.5	1130	1,400	No rain, flow receding
		4.5	1417	2,300	No rain, flow receded ~2 feet from high
		4.5	1550	1,200	No rain, normal depth
11/25/96	u/s of mouth	0.01	1040	300 *	Light rain
		0.01	1227	100	No rain
	McCrory Creek Road, u/s of I-40 beside airport property	4.0	1030	200 *	Light rain
		4.0	1140	600	No rain

* Average of one Eckenfelder sample and two Warner Labs samples.

Table A-3 1996 Dry Weather Survey Data – Stoners Creek

Waterbody	Location	RM	Date	Fecal Coliform [col./100 ml]
Stoners Creek	d/s Central Pike	0.95	4/3/96	100
	u/s Intersection of Hermitage Industrial Dr. & Central Pike	1.19	4/3/96	76
	Near intersect. Baltic Dr. & Panama Dr.	1.49	4/3/96	23
	u/s Old Hickory Blvd.	1.69	4/3/96	23
	u/s of tributary	1.80	4/3/96	33
	Old Lebanon Dirt Road	3.05	4/3/96	26.5
	u/s of trib. & d/s Andrew Jackson Pkwy.	3.56	4/3/96	34
	u/s of tributary	3.78	4/3/96	26
	u/s of tributary	4.24	4/3/96	44
	Tulip Grove Road	5.06	4/3/96	20
	u/s of Tulip Grove Road	5.60	4/4/96	34
	u/s of tributary	5.71	4/4/96	8
	u/s of Chandler Road & tributary	6.01	4/4/96	24
	u/s of tributary & d/s of Wilson Co. line	6.11	4/4/96	31
	Near Old Lebanon Dirt Rd. & u/s of trib.	6.62	4/4/96	70
Trib. (RM 1.25)	d/s of Chessie/Seaboard RR bridge	0.02	4/3/96	200
	d/s of Chessie/Seaboard RR bridge	0.02	4/3/96	48
Trib. (RM 1.35)	Off main branch, taken from groundwater of old plant effluent line	1.30	4/4/96	49
Trib. (RM 1.68)	Small branch off left bank	0.01	4/3/96	22
Trib. (RM 1.79)	Near confluence	0.02	4/3/96	56
Trib. (RM 3.53)	~0.1 mi. d/s of Andrew Jackson Pkwy.	0.00	4/3/96	48
Trib. (RM 3.65)	Small branch off right bank	0.01	4/3/96	66
Trib. (RM 3.70)	Small tributary off left bank	0.08	4/3/96	84
Trib. (RM 4.08)	Trib. off left bank at sewer crossing	0.00	4/3/96	16
Trib. (RM 4.08)	Trib. off right bank at sewer crossing	0.00	4/3/96	7
Trib. (RM 4.21)	Tributary off left bank	0.05	4/3/96	30
Trib. (RM 4.22)	Small branch	0.01	4/3/96	78
Scotts Hollow Br.	Tulip Grove Road	0.01	4/3/96	54
Trib. (RM 5.70)	Small stream off right bank	0.01	4/4/96	17
Trib. (RM 6.00)	Chandler Road	0.01	4/4/96	44
Trib. (RM 6.10)	Near confluence	0.01	4/4/96	14
Trib. (RM 6.61)	Near Old Lebanon Dirt Road	0.01	4/4/96	14

Table A-4 1996 Wet Weather Monitoring Results – Stoners Creek

Date	Location	RM	Time	Fecal Coliform col./100 ml	Observations
9/21/96	Near Brandau Road	0.5	0716	1,100	Light rain
		0.5	0859	900	Mod. rain, 2 ft. deep
		0.5	1048	4,400	Light rain, 2 ft. deep
		0.5	1334	8,700	Light rain
		0.5	1503	3,100	No rain
		0.5	1623	2,100	No rain
	Tulip Grove Road	5.0	0742	3,200	Moderate rain
		5.0	0924	9,000	Moderate rain
		5.0	1110	1,500	V. light rain, no ch. in depth
		5.0	1357	720	No rain, no ch. in depth
		5.0	1526	1,000	No rain
11/25/96	Near Brandau Road	0.5	1020	700 *	No rain
		0.5	1130	100	No rain
	Chandler Road	6.0	1035	100 *	Light rain
		6.0	1145	100	No rain

* Average of one Eckenfelder sample and two Warner Labs samples.

MWS also conducted monitoring in relevant waterbodies listed as impacted due to pathogens on the 1998 303(d) list. This sampling was performed to support recommendations to the Division of Water Pollution Control (DWPC) regarding the 303(d) status of these waterbodies. The results of this monitoring for the years 2000 and 2001-2003 for are summarized in Tables A-5 & A-6 for McCrory Creek and A-5m & A-7 for Stoners Creek (MWS, 2002).

Table A-5 Fecal Coliform Monitoring Data for McCrory Creek & Stoners Creek - 2000

Sample Date	Fecal Coliform Monitoring Data	
	McCrory Ck. (~RM 0.3)	Stoners Ck. (~RM 0.5)
	[CFU/100 ml]	[CFU/100 ml]
3/30/00		8
3/31/00	29	52
4/6/00	11	520
4/7/00	620	113
4/10/00	6	15
4/18/00	61	25
4/20/00	52	128
4/27/00	130	210
4/30/00	100	30
5/1/00	260	30
5/2/00	470	59
5/3/00	860	113
5/31/00	450	60
6/1/00	650	140
6/2/00	890	90
6/5/00	360	80
6/6/00	820	70
6/7/00	110	43
6/8/00	140	40
6/9/00	110	55
6/12/00	180	41
6/13/00	60	93
7/10/00	310	
7/11/00	250	118
7/13/00		169
7/14/00		270
7/18/00	40	98
8/2/00	280	230
8/7/00	50	224
8/8/00	460	290
8/9/00	70	
8/10/00	90	**2890**
8/15/00	60	270
1/8/01	270	30
1/9/01	130	148
1/10/01	10	1
1/15/01	72	92
1/16/01	60	51
1/22/01	340	94
1/23/01	90	52
1/24/01	19	16
1/25/01	38	18
1/26/01	23	26

Table A-6 MWS Pathogen Monitoring for McCrory Creek, 2001 –2003

Waterbody	RM	Date	Monitoring Results FC [CFU/100 ml]	Monitoring Results EC [CFU/100 ml]
McCrory Creek	0.3	Feb-01	10	48
		Jun-01	89	47
		Nov-01	28	37
		Feb-02	190	290
		May-02	82	57
		May-02 (D)	75	24
		Aug-02	110	93
		Aug-02 (D)	110	78
		Oct-02	320	370
		Jan-03	—	61
		Feb-03	110	80
		Apr-03	—	770
	1.3	Feb-01	150	179
		Jun-01	940	490
		Jun-01 (D)	650	270
		Jun-01 (R)	450	160
		Nov-01	150	160
		Feb-02	210	260
		Feb-02 (D)	200	260
		May-02	660	816
		Aug-02	220	180
		Apr-03	—	980
	4.1	Feb-01	40	25
		Jun-01	320	280
		Nov-01	34	20
		Feb-02	90	82
		May-02	85	63
		Aug-02	410	170
		Apr-03	—	60

Note: D – Duplicate; R – Resample; FC – Fecal Coliform; EC – E. coli.

Table A-7 MWS Pathogen Monitoring for Stoners Creek, 2001 -2003

Waterbody	RM	Date	Monitoring Results FC [CFU/100 ml]	Monitoring Results EC [CFU/100 ml]
Stoners Creek	0.5	Feb-01	30	10
		Jun-01	170	100
		Jun-01 (D)	220	180
		Nov-01	160	120
		Feb-02	160	170
		Feb-02 (D)	150	200
		May-02	110	170
		Aug-02	210	89
		Oct-02	150	200
		Jan-03	—	47
		Feb-03	28	26
		Apr-03	—	96
	2.1	Feb-01	180	387
		Jun-01	180	130
		Nov-01	58	46
		Feb-02	130	100
		May-02	240	330
		May-02 (D)	330	260
		Aug-02	82	93

Note: D – Duplicate; R – Resample; FC – Fecal Coliform; EC – E. coli.

APPENDIX B

Dynamic Loading Model Methodology

DYNAMIC LOADING MODEL METHOD

B.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for TMDL analyses of pathogen impaired waters in the Stones River watershed. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF) and is well suited to demonstrate compliance with the 200 counts/100 ml geometric mean standard. LSPC was used to simulate the buildup and washoff of fecal coliform bacteria from land surfaces in response to storm events, loading from point sources, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet target concentrations (standard - MOS) calculated.

B.2 Model Set Up

The Stones River watershed was delineated into subwatersheds in order to: 1) facilitate model hydrologic and water quality calibration; and 2) characterize relative fecal coliform contributions from significant contributing drainage areas. Boundaries were constructed so that subwatershed "pour points" coincided, when possible, with USGS continuous stream gages and water quality monitoring stations. Watershed delineation was based on the Rf3 stream coverage and Digital Elevation Model (DEM) data. This discretization allows management and load reduction alternatives to be varied by subwatershed.

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support water quality model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics. Results of WCS subwatershed characterizations were input into the Fecal Coliform Loading Estimation Spreadsheet (FCLES), developed by Tetra Tech, Inc., to estimate LSPC input parameters associated with fecal coliform buildup (loading rates) and subsequent washoff from land surfaces. In addition, FCLES was used to estimate direct sources of fecal coliform loading to water bodies from leaking septic systems and animals having access to streams. Information from the WCS and FCLES utilities were used as initial input for variables in the LSPC model.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. The pattern and intensity of rainfall affects the buildup and washoff of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. Weather data from the multiple meteorological stations were available for the time period from January 1970 through December 2001. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (1/1/92 – 9/30/02) used for TMDL analysis.

B.3 Model Calibration

The calibration of the LSPC watershed model involves both hydrology and water quality components. The model must be first calibrated to appropriately represent hydrologic response to meteorological conditions before water quality calibration and subsequent simulations can be performed. Due to the lack of comprehensive data sets at the mouths of the listed waterbodies, data collected at the nearest locations were used to calibrate the subwatershed models.

B.3.1 Hydrologic Calibration

Hydrologic calibration of the watershed model involves comparison of simulated stream flow to historic stream flow data from USGS stream gaging stations for the same period of time. The USGS continuous record station located in Stoners Creek near Hermitage, Tennessee (USGS 03430147) was selected as the basis of the hydrology calibration. Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed stream flow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The calibration involved comparison of simulated and observed hydrographs until statistical stream volumes and flows were within acceptable ranges as reported in the literature (Lumb, et al., 1994). Statistical stream volumes and flows were evaluated over the entire 10-year simulation period . The resulting calibrated model was considered to best represent watershed hydrology over a wide range of meteorological conditions. The results of hydrologic calibration for Stoners Creek at USGS Station 03430147 (ref.: Figure 5) are shown in Table B-1 and Figures B-1 through B-10.

B.3.2 Water Quality Calibration

Water quality calibration involves comparison of simulated instream fecal coliform concentrations to monitoring data concentrations on the same date. An LSPC model, using values for hydrologic variables derived from the hydrologic calibration, was configured for each impaired waterbody so that the model pour point corresponded to the location of the water quality monitoring station. Watershed data, produced with WCS, were processed through the FCLES spreadsheet to generate fecal coliform loading data for use as <u>initial</u> input for model pollutant loading variables. Instream decay of fecal coliform bacteria was conservatively estimated using the values reported in Lombardo (1972). For freshwater streams, decay ranges from 0.008 hr^{-1} to 0.13 hr^{-1}, with a median value of 0.048 hr^{-1}. The median value was used as initial input to model simulations. Derivation of the various loading variables is discussed in the subsections that follow.

Model variables were adjusted, as necessary, within reasonable limits until acceptable agreement was achieved between simulated and instream observed data was achieved. Model variables adjusted include:

- Rate of fecal coliform bacteria accumulation
- Maximum storage of fecal coliform bacteria
- Rate of surface runoff that will remove 90% of stored fecal coliform bacteria
- Concentration of fecal coliform bacteria in interflow
- Concentration of fecal coliform bacteria in groundwater
- Concentration of fecal coliform bacteria and rate of flow of "other direct sources".
- In-stream fecal coliform decay (die-off) rate.

B.3.2.1 Point Sources

For existing conditions, NPDES facilities located in modeled watersheds are represented as point sources of average (constant) flow and concentration based on the facility's flow and effluent fecal coliform concentration as reported on Discharge Monitoring Reports (DMRs).

B.3.2.2 Nonpoint Sources

A number of nonpoint source categories are not associated with land loading processes and are represented as direct, instream source contributions in the model. These may include, but are not limited to, failing septic systems, leaking sewer lines, animals in streams, illicit connections, direct discharge of raw sewage, and undefined sources. All other nonpoint sources involve land loading of fecal coliform bacteria and washoff as a result of storm events. Only a portion of the load from these sources is actually delivered to streams due to the mechanisms of washoff (efficiency), decay, and incorporation into soil (adsorption, absorption, filtering) before being transported to the stream. Therefore, land loading nonpoint sources are represented as indirect contributions to the stream. Buildup, washoff, and die-off rates are dependent on seasonal and hydrologic processes.

B.3.2.2.1 Wildlife

Wildlife deposit fecal coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes. Fecal coliform loads due to deer are estimated by EPA to be 5.0×10^8 counts/animal/day. The resulting fecal coliform loading on a unit area basis is 3.52×10^7 counts/acre/day.

B.3.2.2.2 Land Application of Agricultural Manure

In the water quality model, livestock populations are distributed to subwatersheds based on information derived from WCS. Fecal coliform loading rates were calculated from livestock populations based on manure application rates, literature values for bacteria concentrations in livestock manure, and the following assumptions:

- Fecal content in manure was adjusted to account for die-off due to known treatment/storage methods.
- Manure application rates from the various animal sources are applied according to application practices throughout the year.
- The fraction of manure available for runoff is dependent on the method of manure application. In the water quality model, the fraction available is estimated based on incorporation into the soil.

Fecal coliform production rates used in the model for beef cattle, dairy cattle, hogs, horses, and chicken are 1.06×10^{11} counts/day/beef cow, 1.04×10^{11} counts/day/dairy cow, 1.24×10^{10} counts/day/hog, 4.18×10^{8} counts/day/horse, and 1.38×10^{8} counts/day/chicken (NCSU, 1994).

B.3.2.2.3 Grazing Animals

Cattle spend time grazing on pastureland and deposit feces onto the land. During storm events, a portion of this material containing fecal coliform bacteria is transported to streams. Beef cattle are assumed to spend all their time in pasture. The percentage of feces deposited during grazing time is used to estimate fecal coliform loading rates from pastureland. Because there is no assumed monthly variation in animal access to pastures in middle Tennessee, the fecal loading rate does not vary significantly throughout the year. Therefore, the loading rate to pastureland is assumed to be relatively constant within each subwatershed. However, this rate varies across subwatersheds depending on livestock population. The approximate loads from grazing cattle vary from 1.09×10^{10} to 5.09×10^{10} counts/acre-day. Contributions of fecal coliform from wildlife (as noted in Section B.3.2.2.1) are also included in these rates.

B.3.2.2.4 Urban Development

Urban land use represented in the MRLC database includes areas classified as: high intensity commercial, industrial, transportation, low intensity residential, high intensity residential, and transitional. Associated with each of these classifications is a percent of the land area that is impervious. A single, area-weighted loading rate from urban areas is used in the model and is based on the percentage of each urban land use type in the watershed and buildup and accumulation rates referenced in Horner (Horner, 1992). In the water quality calibrated model, this rate is 1.0×10^{9} counts/acre-day and is assumed constant throughout the year.

B.3.2.2.5 Other Direct Sources

As previously stated, there are a number of nonpoint sources of fecal coliform bacteria that are not associated with land loading and washoff processes. These include animal access to streams, failing septic systems, illicit discharges, and other undefined sources. In each watershed, these miscellaneous sources have been modeled as point sources of constant flow and fecal coliform concentration and are referred to as “other direct sources” in this document. The initial baseline values of flow and concentration were estimated using the FCLES spreadsheets and the following assumptions:

- The load attributed to animals having access to streams is initially based on the beef cow population in the watershed. The percentage of animals having access to streams is derived from assumptions on animals in operations that are adjacent to streams and seasonal and behavioral assumptions. Literature values were used to estimate the fecal coliform bacteria concentration in beef cow manure.

- The initial baseline loads attributable to leaking septic systems is based on an assumed failure rate of 20 percent.

Flow and concentration variables were adjusted during water quality calibration to best-fit simulated in-stream fecal coliform concentrations during dry weather conditions.

B.3.2.3 Water Quality Calibration Results

Water quality calibration results show that, overall, each waterbody model adequately simulates peaks in fecal coliform bacteria in response to rainfall events and pollutant loading dynamics. In some cases, an observed value is not simulated in the model well due to differences in rainfall at the meteorological station as compared to localized rainfall occurring in the watershed, or is the result of an unknown source that is not included in the model.

The results of the water quality calibrations for Stoners Creek, McCrory Creek, and Christmas Creek are shown in Figures B-11 through B-15.

B.4 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For TMDL analyses using LSPC, both an explicit and implicit MOS were used. The explicit MOS is 20 counts/100 ml, equal to 10% of the 200 counts/100 ml geometric standard. This results in a target fecal coliform concentration of 180 counts/100 ml. The implicit MOS includes the use of conservative modeling assumptions and a 10-year continuous simulation that incorporates a wide range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; and all land uses connected directly to streams.

Note: In this document, the water quality standard is the instream goal. The term “target concentration” reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 5.0.

B.5 Determination of Existing Loading

B.5.1 Dynamic Loading Model

The critical condition for nonpoint source fecal coliform loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, fecal coliform bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low stream flow when dilution is minimized. Both conditions are simulated in the water quality model.

For each modeled subwatershed, the 10-year simulation period was used to generate daily mean instream concentrations. These were used to calculate continuous 30-day geometric mean concentrations which were then compared to the target concentration. The 10-year simulation period contained a range of hydrologic conditions that included both low and high stream flows. The 30-day critical period for each subwatershed is the period preceding the highest simulated violation of the geometric mean standard. The magnitude of the highest peak, together with the corresponding simulated flow, represents the existing fecal coliform loading to the waterbody.

The results of the 10-year simulations used to determine existing conditions for impaired waterbodies are shown in Figures B-16, B-17, & B-18. The highest simulated 30-day geometric mean concentration for each waterbody is:

Waterbody	Date	30-Day Geometric Mean Concentration [cts/100 ml]
McCrory Creek	12/9/98	576.8
Stoners Creek	12/16/96	104.1
Christmas Creek	12/22/01	399.6

B.5.2 Monitoring Data

Due the lack of sufficient data (minimum of 10 samples in a maximum 30-day period), the evaluation of instream water quality, with respect to the 30-day geometric mean standard for fecal coliform, is usually accomplished through the use of a dynamic loading model such as LSPC. The quantity of data collected by MWS in McCrory Creek and Stoners Creek (ref.: Table A-5), however, allows the calculation of geometric mean fecal coliform concentrations for three time periods:

	Geometric Mean Fecal Coliform Concentration	
Sample Dates	McCrory Creek (~RM 0.3)	Stoners Creek (~RM 0.5)
4/6/00 – 5/3/00	105.9	71.6
5/31/00 – 6/13/00	259.9	65.8
1/8/01 – 1/26/01	61.5	30.8

B.6 Determination of TMDLs

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or <u>other appropriate measure</u>.

For the purposes of these analyses, fecal coliform TMDLs are expressed as the percent reduction in instream loading required to decrease the maximum existing instream 30-day geometric mean concentration (as defined in Section B.5) to the target of 180 counts/100 ml. The required reduction can be determined directly using the following equation:

$$\text{TMDL} = \text{RILR} = \frac{[(C)\ (Q)\ (\text{Const})]_{\text{Existing}} - [(C)\ (Q)\ (\text{Const})]_{\text{Target}}}{[(C)\ (Q)\ (\text{Const})]_{\text{Existing}}} \times 100$$

where: RILR = Required Instream Load Reduction [%]
C = Instream Concentration [counts/100 ml]
Q = Daily Mean Flow [cfs]
Const = Unit Conversion Constant

Since the stream flow for the existing condition is equal to the stream flow for the target condition on a particular day:

$$\text{TMDL} = \text{RILR} = \cancel{\frac{(Q)\ (\text{Const})}{(Q)\ (\text{Const})}} \times \frac{[C]_{\text{Existing}} - [C]_{\text{Target}}}{[C]_{\text{Existing}}} \times 100$$

therefore:

$$\text{TMDL} = \text{RILR} = \frac{[C]_{\text{Existing}} - [C]_{\text{Target}}}{[C]_{\text{Existing}}} \times 100$$

As an example, for Christmas Creek, the simulated 30-day geometric mean concentration for the existing loading condition in Christmas Creek (ref.: Section B.5) is 399.6 counts/100 ml. The required instream load reduction is calculated by:

$$\text{TMDL} = \text{RILR} = \frac{(399.6 \text{ cts/100 ml}) - (180 \text{ cts/100 ml})}{(399.6 \text{ cts/100 ml})} \times 100$$

$$\text{TMDL} = \text{RILR} = 55.0\%$$

With respect to existing conditions in McCrory Creek and Stoners Creek, both the maximum simulated 30-day geometric mean concentrations (Section B.5.1) and the geometric mean concentrations calculated from monitoring data (Section B.5.2) were considered. In each case, the highest value was used to calculate required load reductions. TMDLs to achieve the 30-day geometric mean target for McCrory Creek, Stoners Creek, and Christmas Creek are summarized in Table B-2.

Table B-1 Hydrologic Calibration Summary of Stoners Creek at USGS Station 03430147

Simulation Name:	**Stoners Creek**	**Simulation Period:**	
		Watershed Area (ac):	12799.94
Period for Flow Analysis			
Begin Date:	**01/01/92**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/01**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**183.34**	Total Observed In-stream Flow:	**192.77**
Total of highest 10% flows:	**107.56**	Total of Observed highest 10% flows:	**114.01**
Total of lowest 50% flows:	**12.61**	Total of Observed Lowest 50% flows:	**11.91**
Simulated Summer Flow Volume (months 7-9):	**10.72**	Observed Summer Flow Volume (7-9):	**11.75**
Simulated Fall Flow Volume (months 10-12):	**36.26**	Observed Fall Flow Volume (10-12):	**33.86**
Simulated Winter Flow Volume (months 1-3):	**85.25**	Observed Winter Flow Volume (1-3):	**95.18**
Simulated Spring Flow Volume (months 4-6):	**51.11**	Observed Spring Flow Volume (4-6):	**51.97**
Total Simulated Storm Volume:	**181.53**	Total Observed Storm Volume:	**191.06**
Simulated Summer Storm Volume (7-9):	**10.25**	Observed Summer Storm Volume (7-9):	**11.32**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-4.89**	10	
Error in 50% lowest flows:	**5.83**	10	
Error in 10% highest flows:	**-5.66**	15	
Seasonal volume error - Summer:	**-8.79**	30	
Seasonal volume error - Fall:	**7.07**	30	
Seasonal volume error - Winter:	**-10.43**	30	
Seasonal volume error - Spring:	**-1.66**	30	
Error in storm volumes:	**-4.99**	20	
Error in summer storm volumes:	**-9.43**	50	

Table B-2 TMDLs for Impaired Subwatersheds

Impaired Waterbody	Existing Condition			TMDL - Required Load Reduction
	Date	Basis	Concentration [cts./100 ml]	[%]
McCrory Creek	12/9/98	Simulation	576.8	68.8
Stoners Creek	12/16/96	Simulation	104.1	NR
Christmas Creek	12/22/01	Simulation	399.6	55.0

NR = No reduction required.

Figure B-1 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1992)

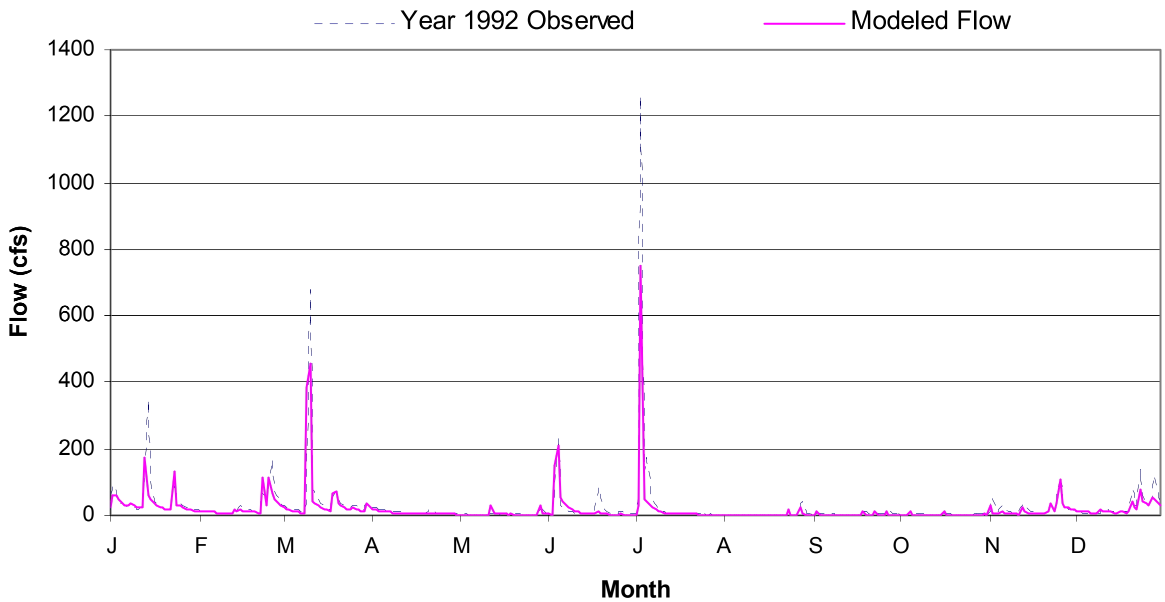


Figure B-2 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1993)

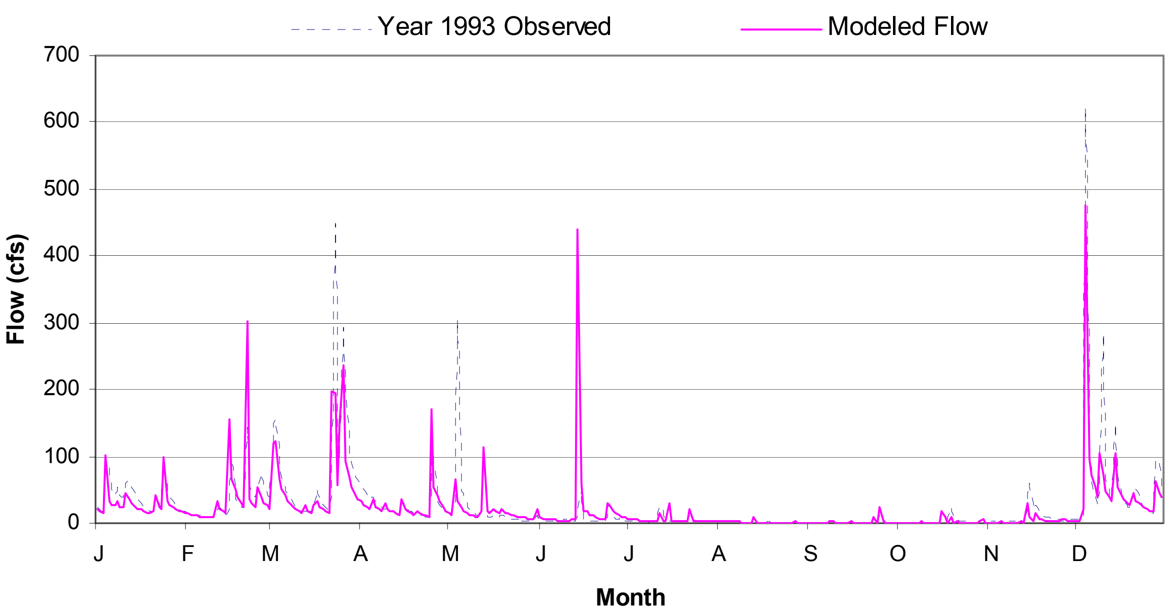


Figure B-3 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1994)

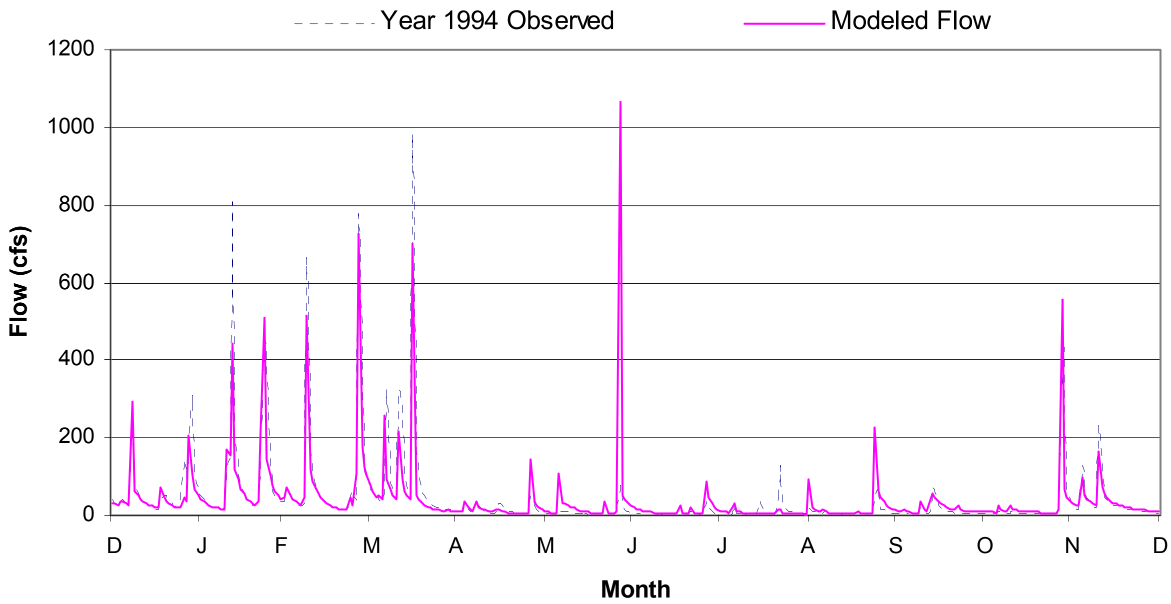


Figure B-4 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1995)

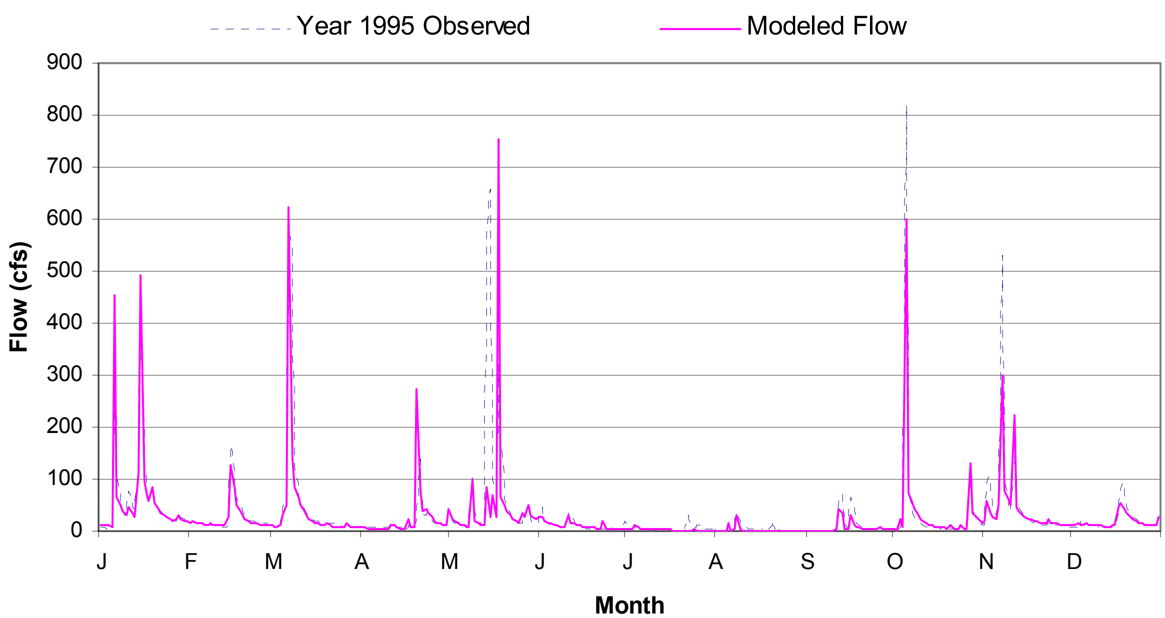


Figure B-5 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1996)

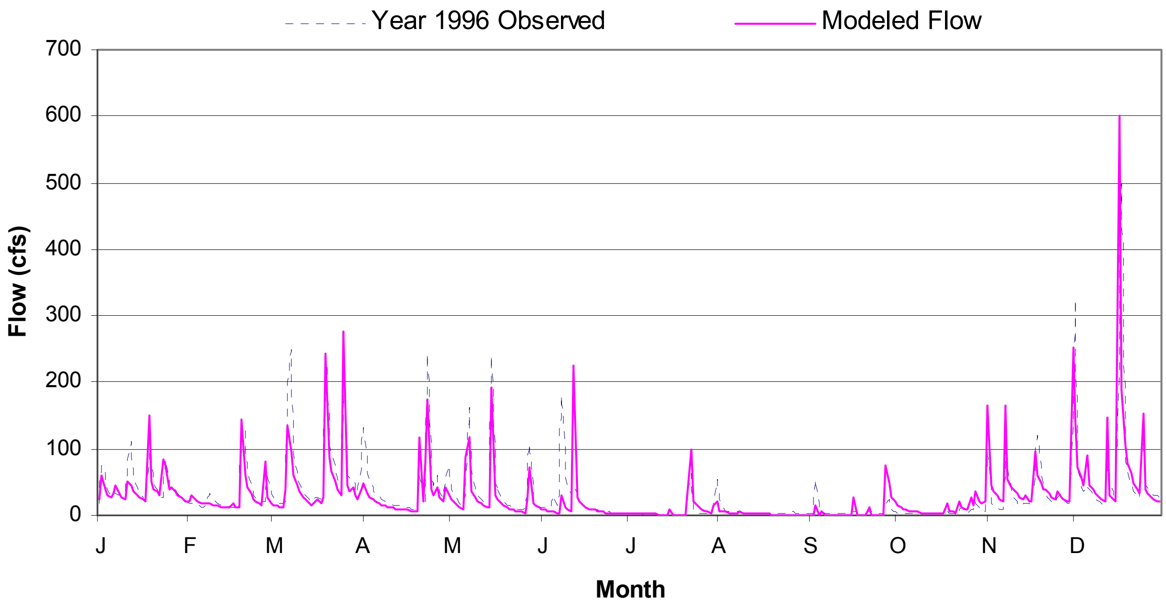


Figure B-6 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1997)

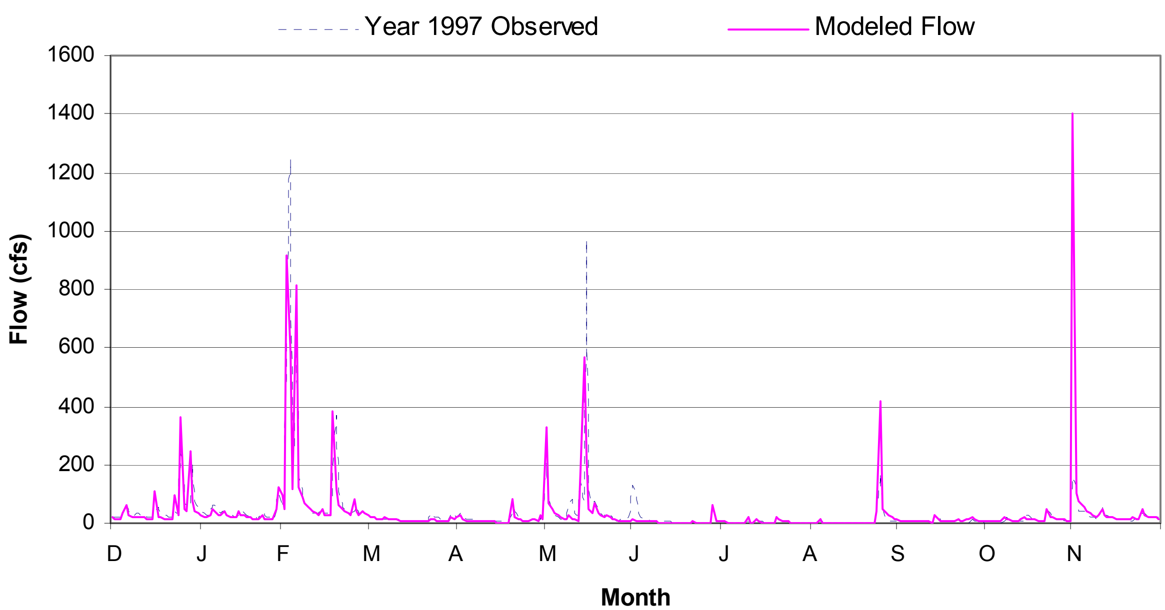


Figure B-7 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1998)

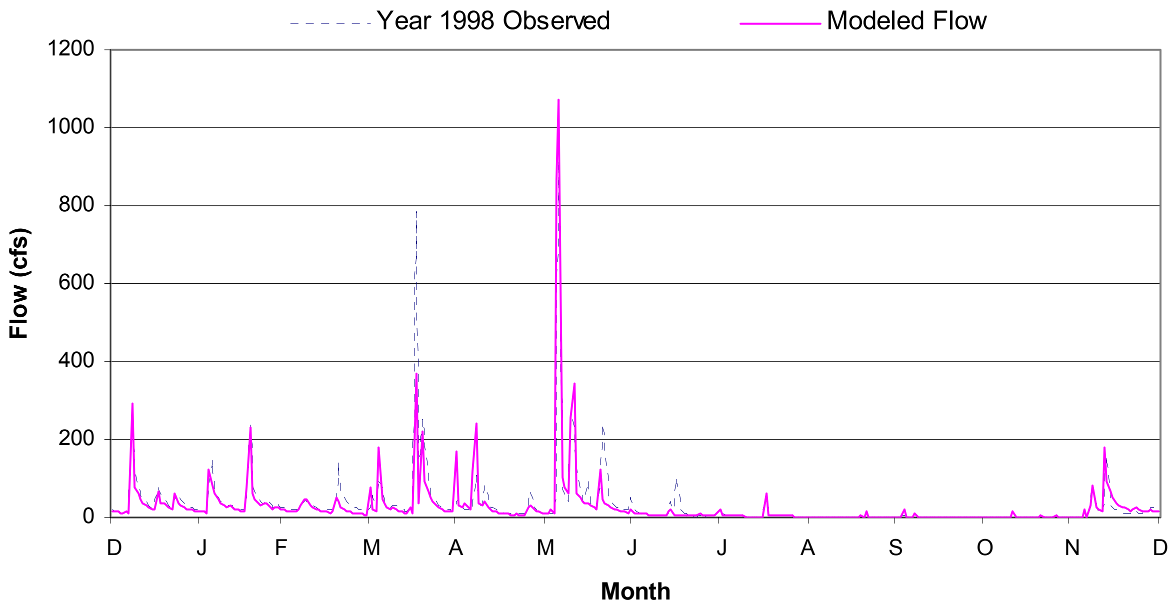


Figure B-8 Hydrologic Calibration of Stoners Creek at USGS 03430147 (1999)

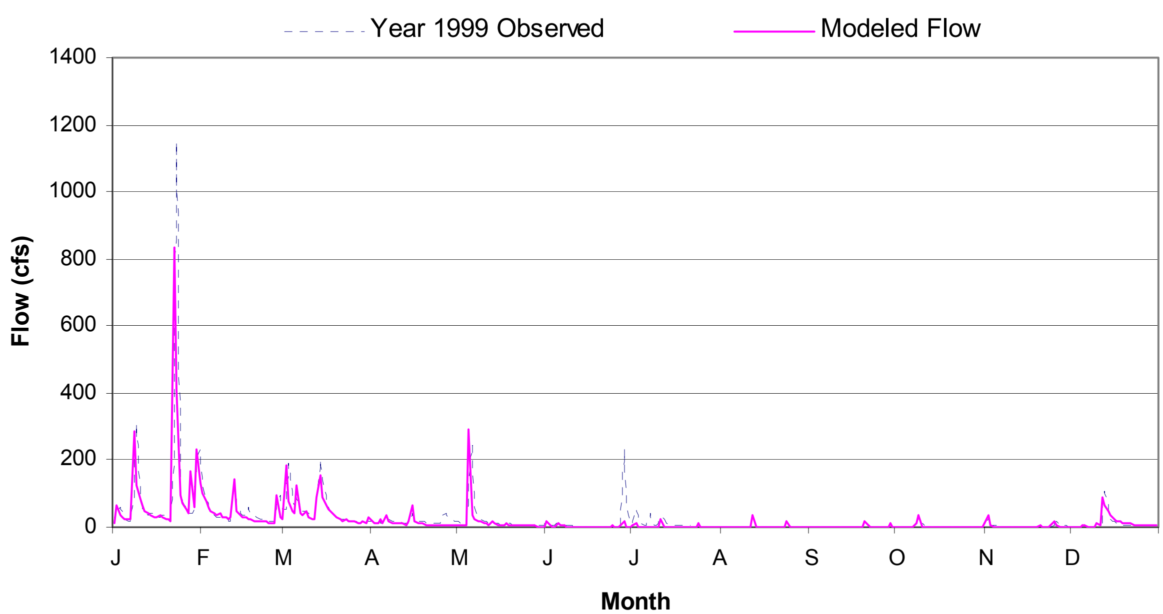


Figure B-9 Hydrologic Calibration of Stoners Creek at USGS 03430147 (2000)

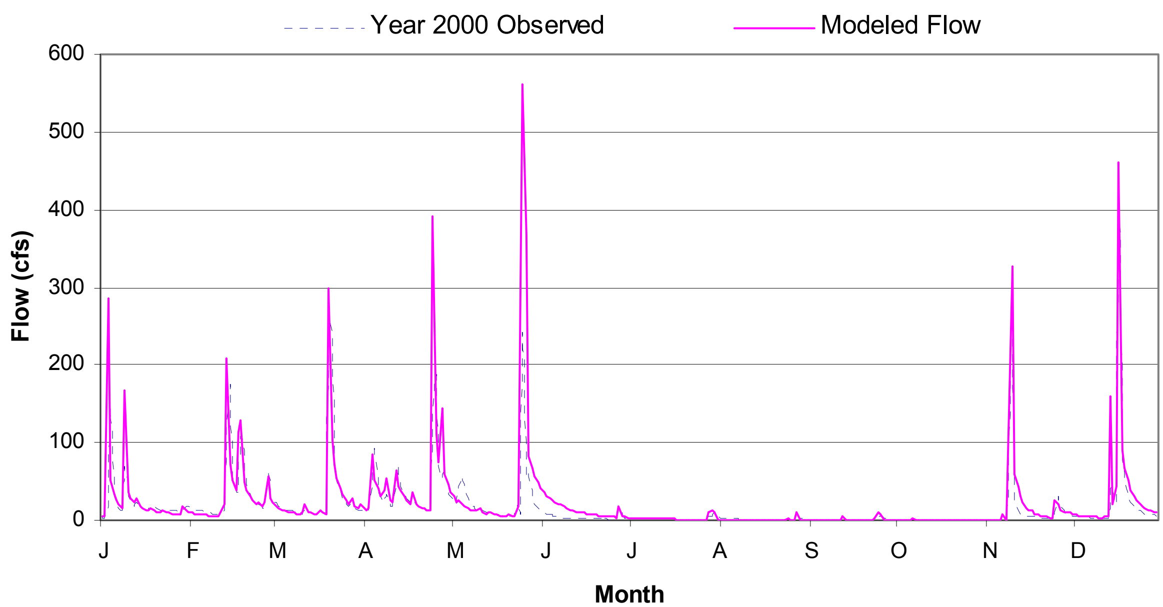


Figure B-10 Hydrologic Calibration of Stoners Creek at USGS 03430147 (2001)

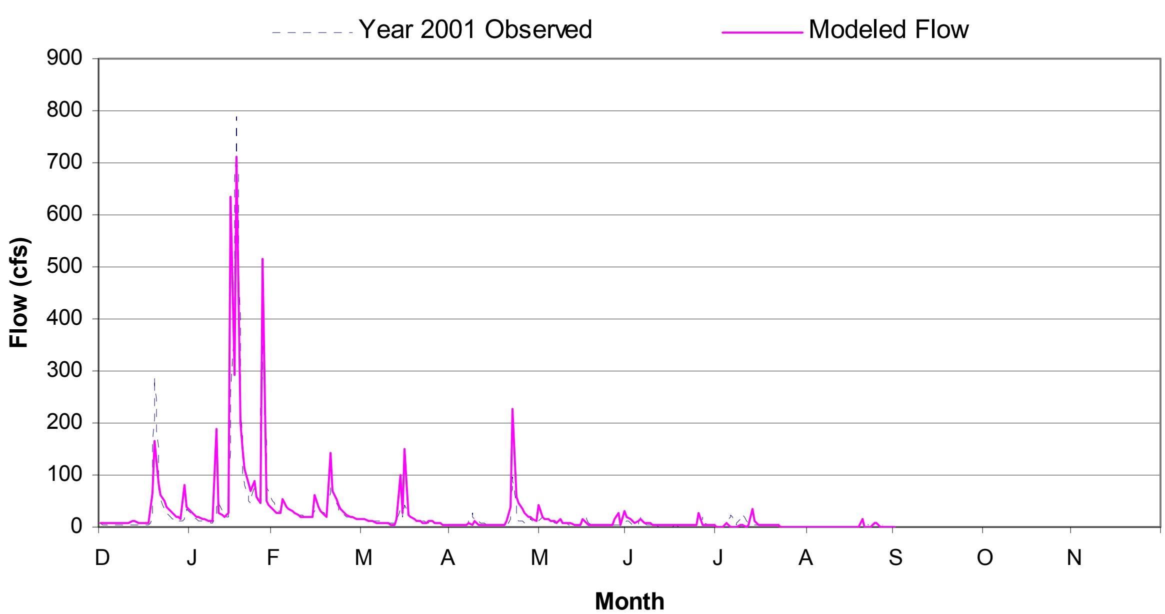


Figure B-11 Water Quality Calibration of Stoners Creek at RM 0.5 (1996)

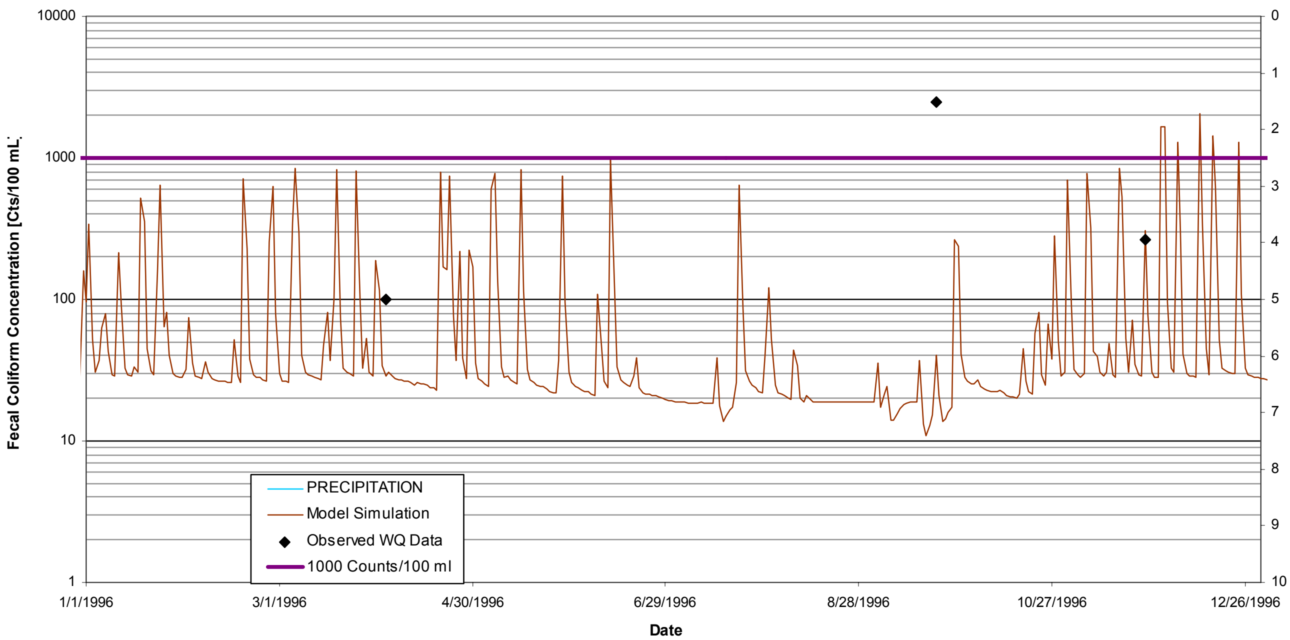


Figure B-12 Water Quality Calibration of Stoners Creek at RM 0.5 (3/00–7/01)

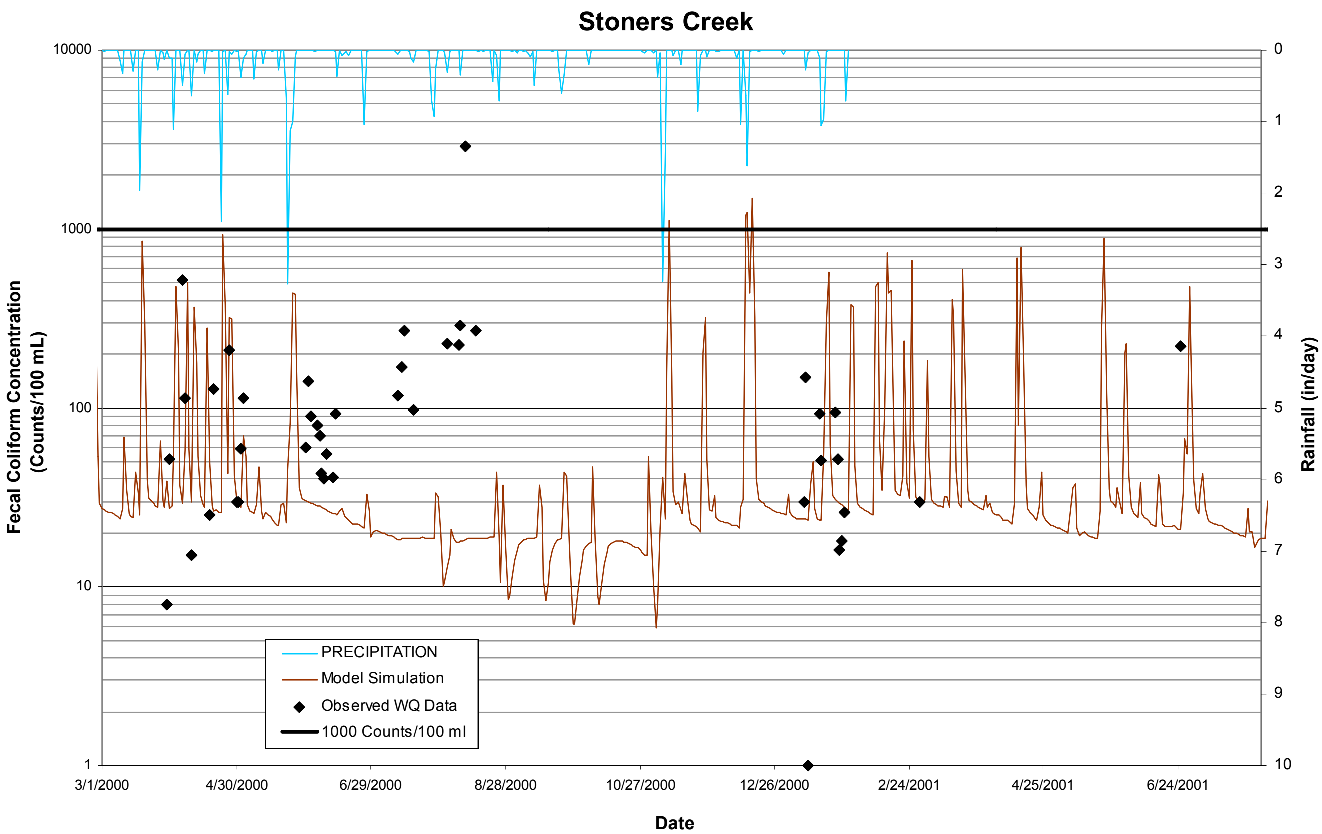


Figure B-13 Water Quality Calibration of McCrory Creek at RM 0.3 (1996)

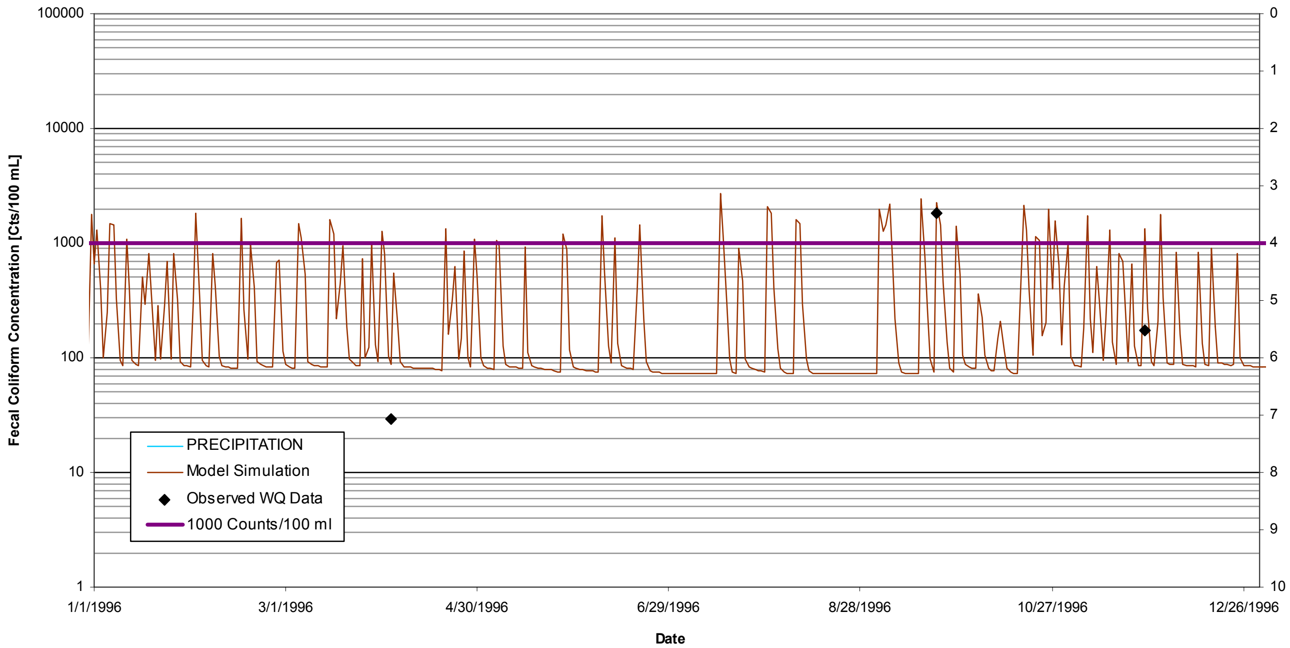


Figure B-14 Water Quality Calibration of McCrory Creek at RM 0.3 (3/00-7/01)

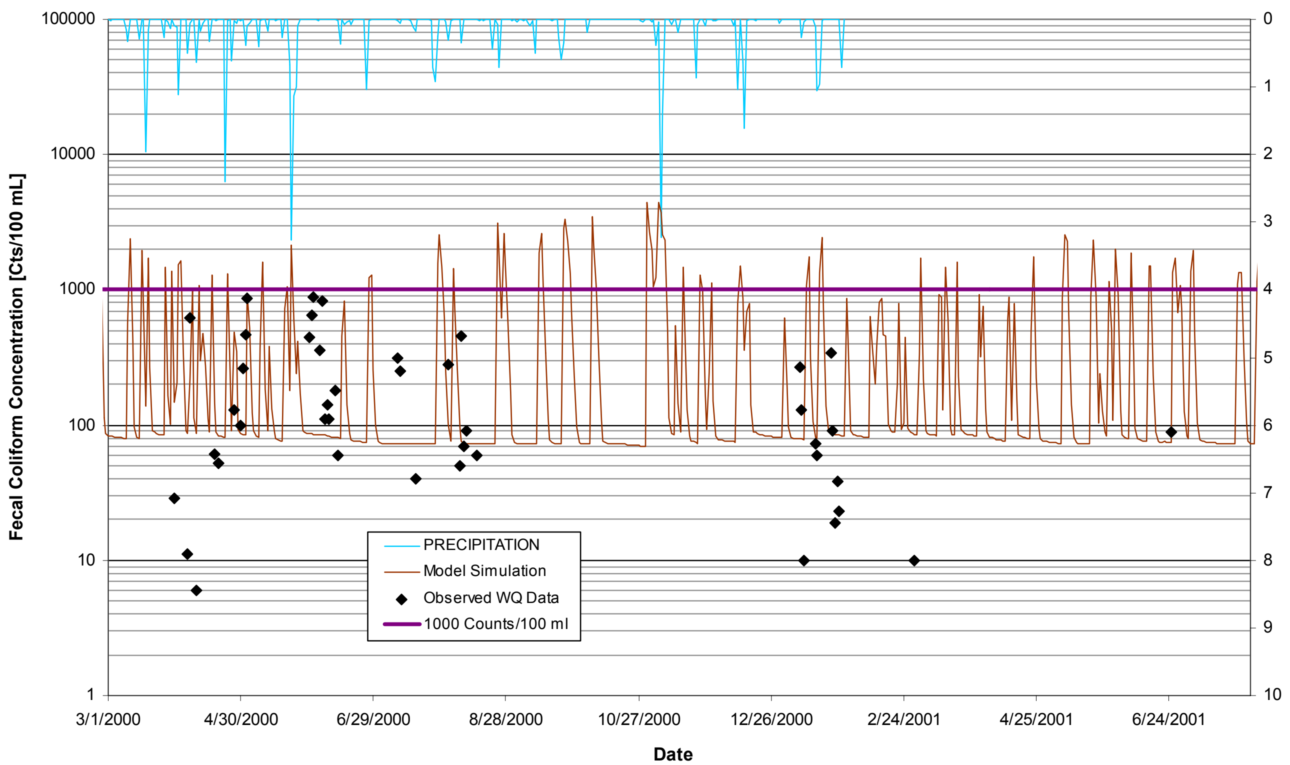


Figure B-15 Water Quality Calibration of Christmas Creek at STORET Station CHRIS000.7RU

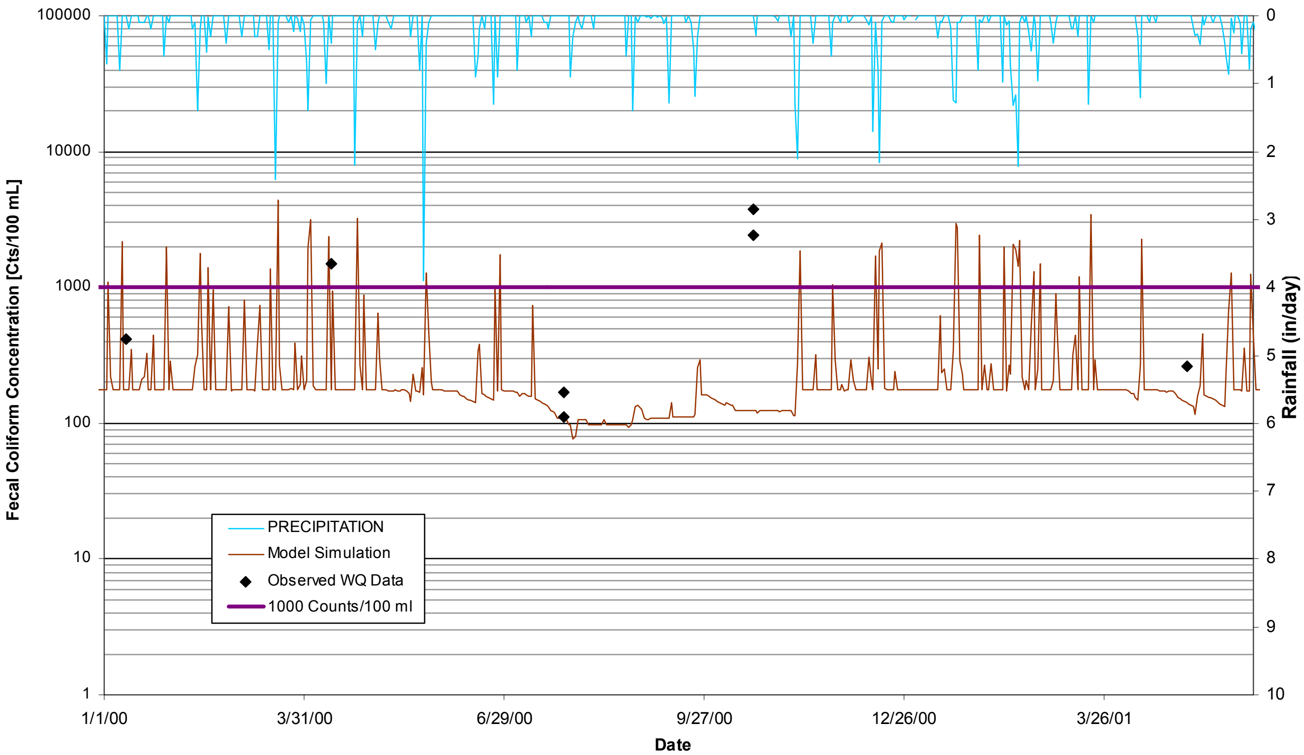


Figure B-16 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Stoners Creek

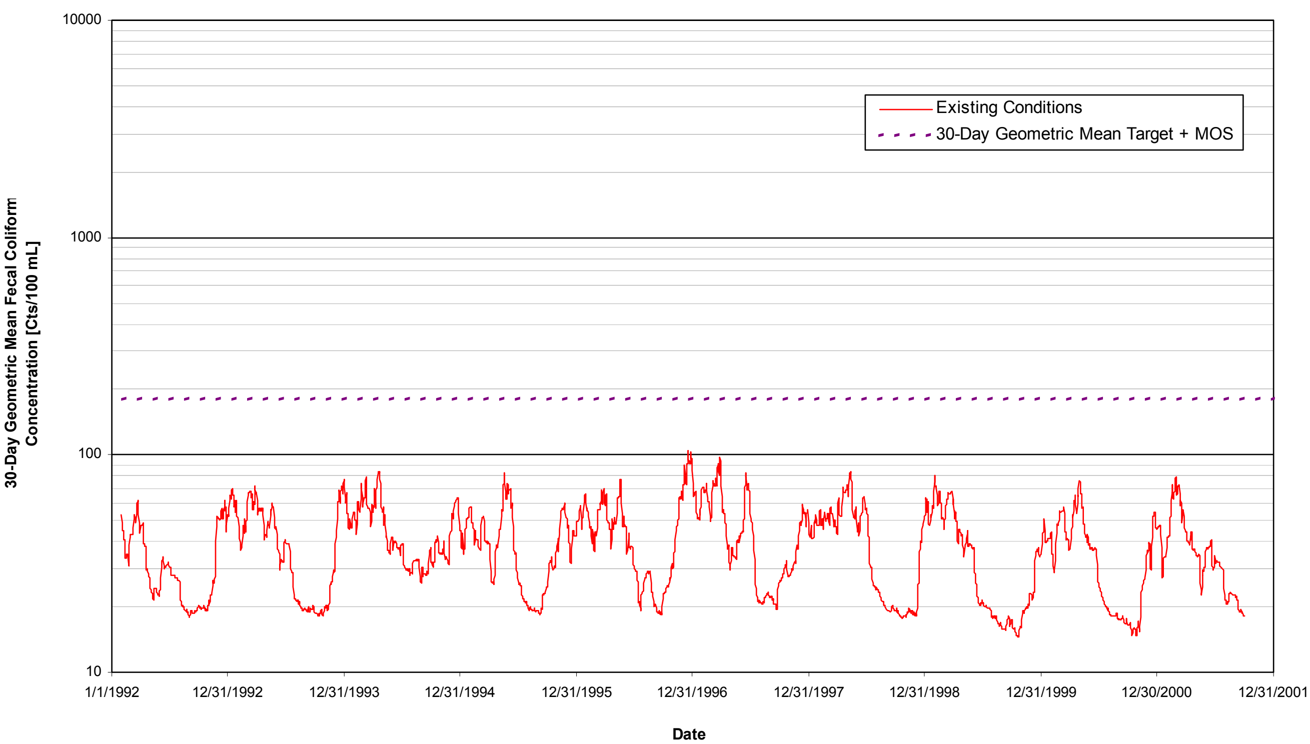


Figure B-17 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for McCrory Creek

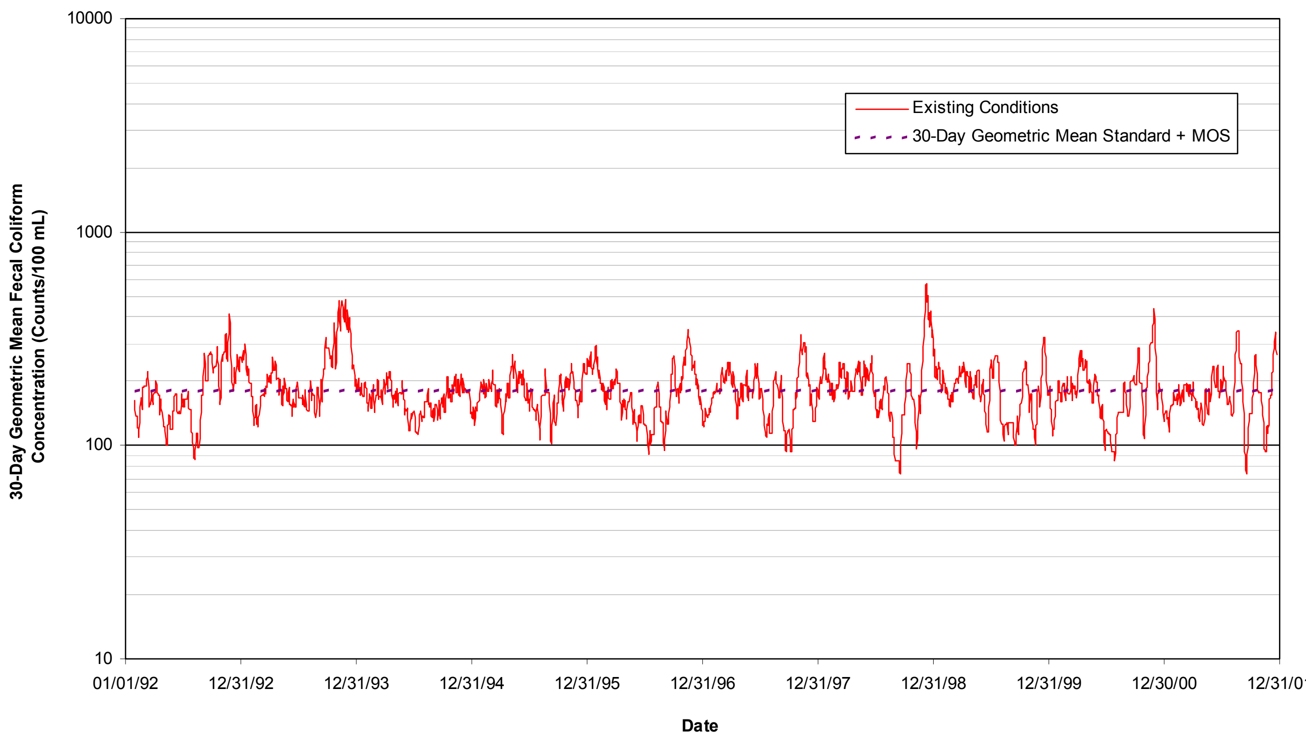
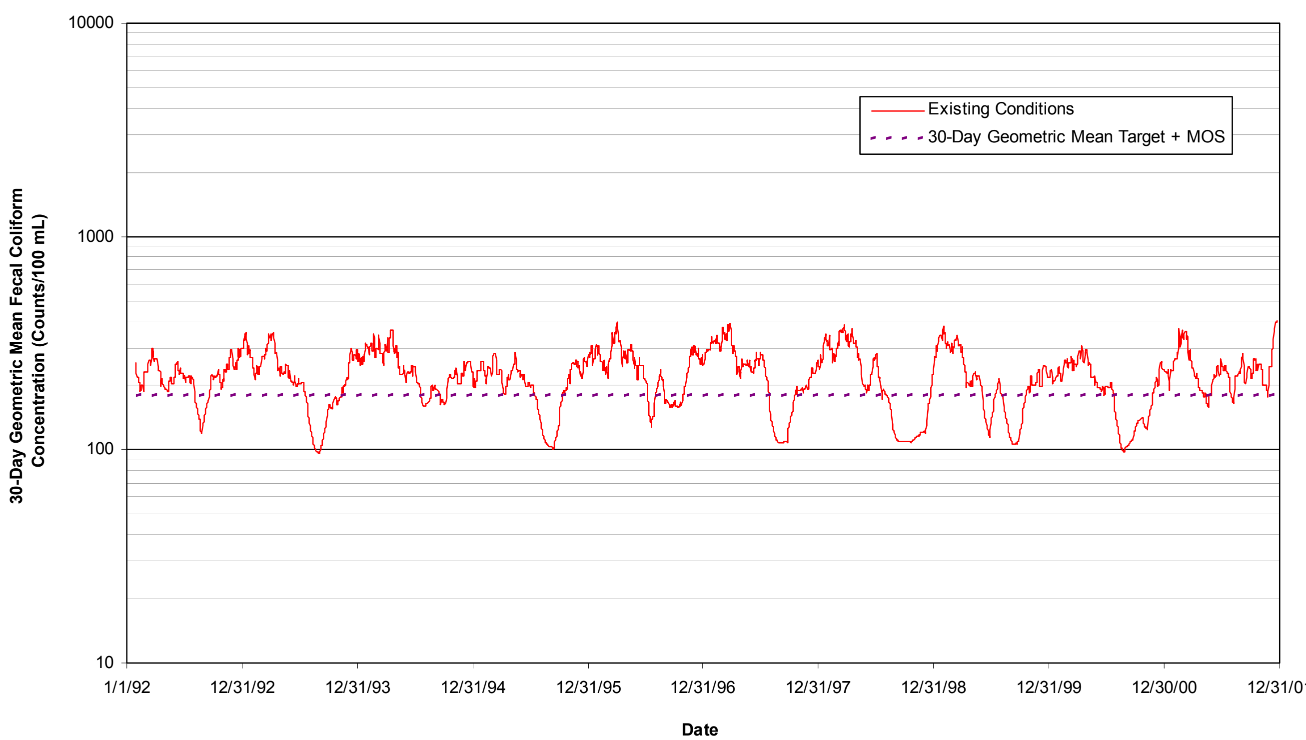


Figure B-18 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Christmas Creek



APPENDIX C

Load Duration Curve Methodology

LOAD DURATION CURVE METHOD

A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and are useful for TMDL analysis:

- Load duration curves can serve as TMDL targets, thereby establishing allowable loading to waterbodies over the entire range of flow.

- Pollutant monitoring data, plotted on a load duration curve, provides a visual depiction of stream water quality with respect to allowable loads. The frequency and magnitude of exceedances are also illustrated.

- Load duration curves can be used to characterize the flow conditions under which exceedances occur. For example, exceedances that occur in the 0% to 10% area of the curve may be considered to represent extreme high flow problems that may be beyond feasible management solutions. Exceedances in the 90% to 100% area reflect drought conditions.

- Different loading mechanisms can dominate at different flow regimes. Exceedances of the load duration curve during high flow conditions may indicate excessive nonpoint source loading associated with rain events, while exceedances at the lower flows can indicate point source problems.

C.1 Development of Flow Duration Curves

Flow duration curves are developed for a waterbody from daily discharges of flow over a period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record correctly represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from USGS continuous-record stations located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as LSPC.

A flow duration curve for Stoners Creek was developed from data from continuous flow data at USGS Station No. 03430147, located on Stoners Creek near Hermitage. Flow duration curves for McCrory Creek and Christmas Creek were derived from the Stoners Creek curve using drainage area ratios. The Stoners Creek flow duration curve is presented in Figure C-1.

C.2 Development of Load Duration Curves

A load duration curve was developed for Stoners Creek using the following procedure:

1. The flow duration curve for Stoners Creek was constructed from data at USGS Station 03430147, which is located at ~RM 5.1 and has a drainage area of approximately 13,184 acres. This flow duration curve was extrapolated to the location of the Metro Water Services (MWS) monitoring station at ~RM 0.5 (drainage area = 18,727 acres) using the ratio of drainage areas.

2. A load-duration curve was generated for Stoners Creek at RM 0.5 by applying the fecal coliform target concentration of 900 cts./100 ml (standard - MOS) to each of the ranked flows used to generate the flow duration curve and plotting the results. The fecal coliform target load corresponding to each ranked daily mean flow is:

   $$(\text{Target Load})_{\text{Stoners Ck}} = (900\ \text{cts./100 ml}) \times (Q) \times (UCF)$$

   where: Q = daily mean flow
   UCF = the required unit conversion factor

3. Daily fecal coliform loads were calculated for each of the water quality samples collected at the MWS monitoring station (ref.: Tables A-4, A-5, & A-6) by multiplying the sample concentration by the flow simulated for the sampling date and the required unit conversion factor. On days where multiple samples were collected, the geometric mean of the sample values was used.

4. Using the flow duration curve developed in Step 1, the “percent of days the flow was exceeded” (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curve developed in Step 2 according to the PDFE. The resulting curve is shown in Figure C-2.

5. For cases where the existing load exceeded the target load, the reduction corresponding to each sample load was determined through comparison with the target load corresponding to the PDFE. The largest reduction of existing fecal coliform load required to meet the TMDL target was considered to be the required load reduction for the subwatershed (see Table C-1).

Load duration curves for McCrory Creek and Christmas Creek were developed in a similar manner. The Stoners Creek flow duration curve (at the USGS station) was extrapolated, by drainage area ratio, to the MWS monitoring site at RM 0.3 on McCrory Creek and STORET Station CHRIS000.7RU on Christmas Creek. The load duration curves for McCrory Creek and Christmas Creek are shown in Figures C-3 & C-4, respectively. The determination of required load reductions for these waterbodies is tabulated in Tables C-2 & C-3.

Figure C-1 Flow Duration Curve for Stoners Creek at USGS Station 03430147

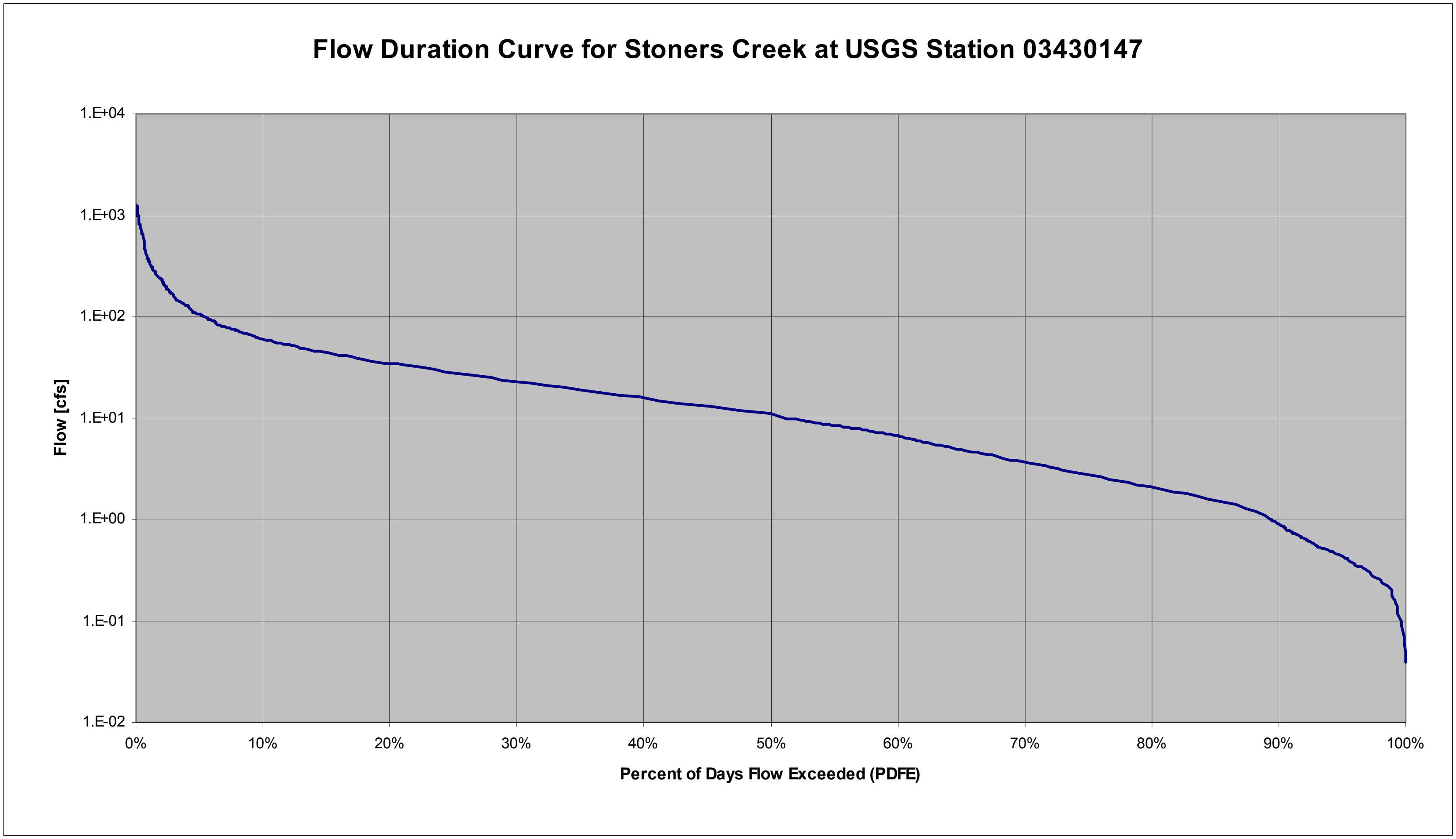


Figure C-2 Load Duration Curve for Stoners Creek at RM 0.5

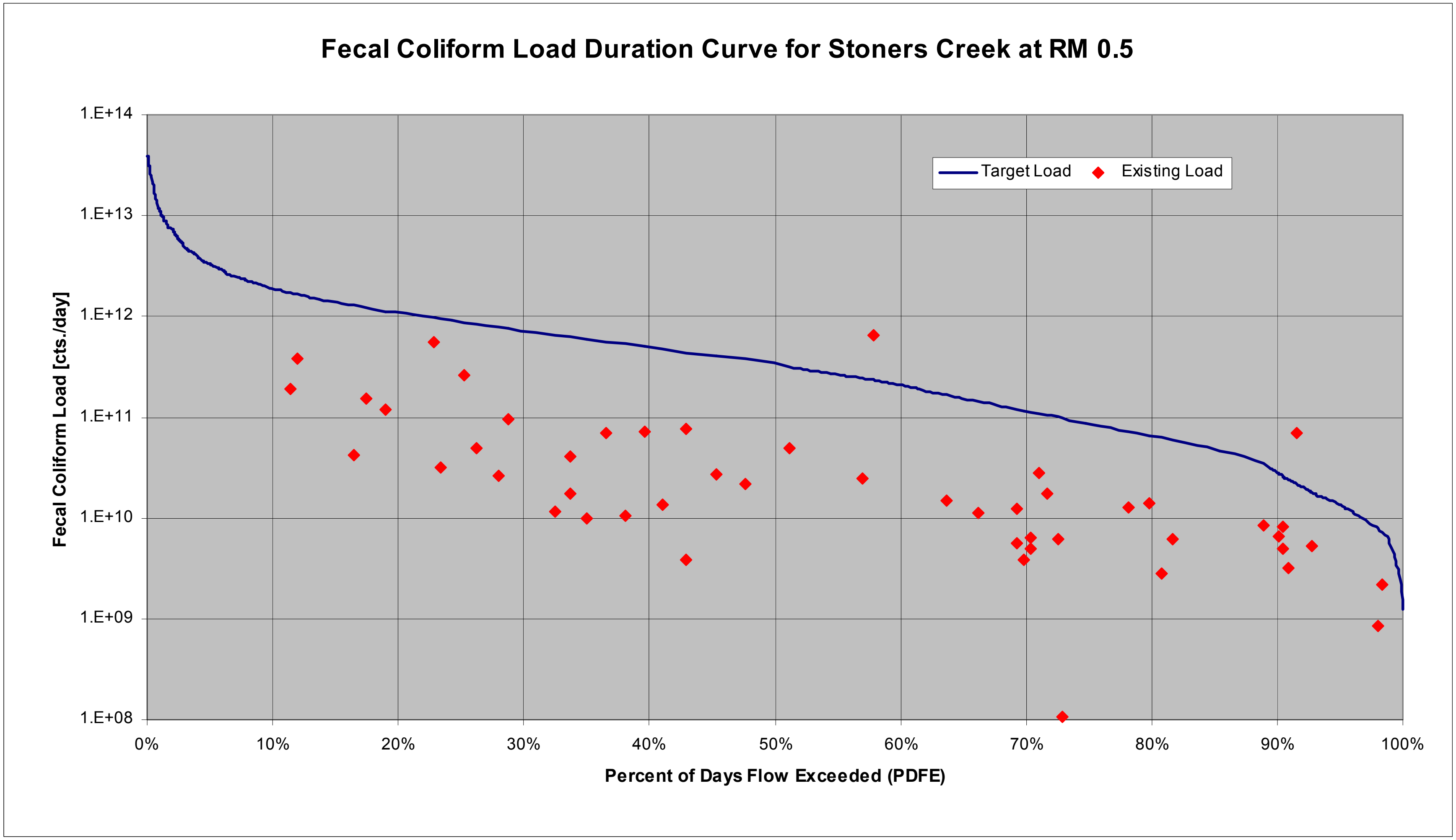


Figure C-3 Load Duration Curve for McCrory Creek at RM 0.3

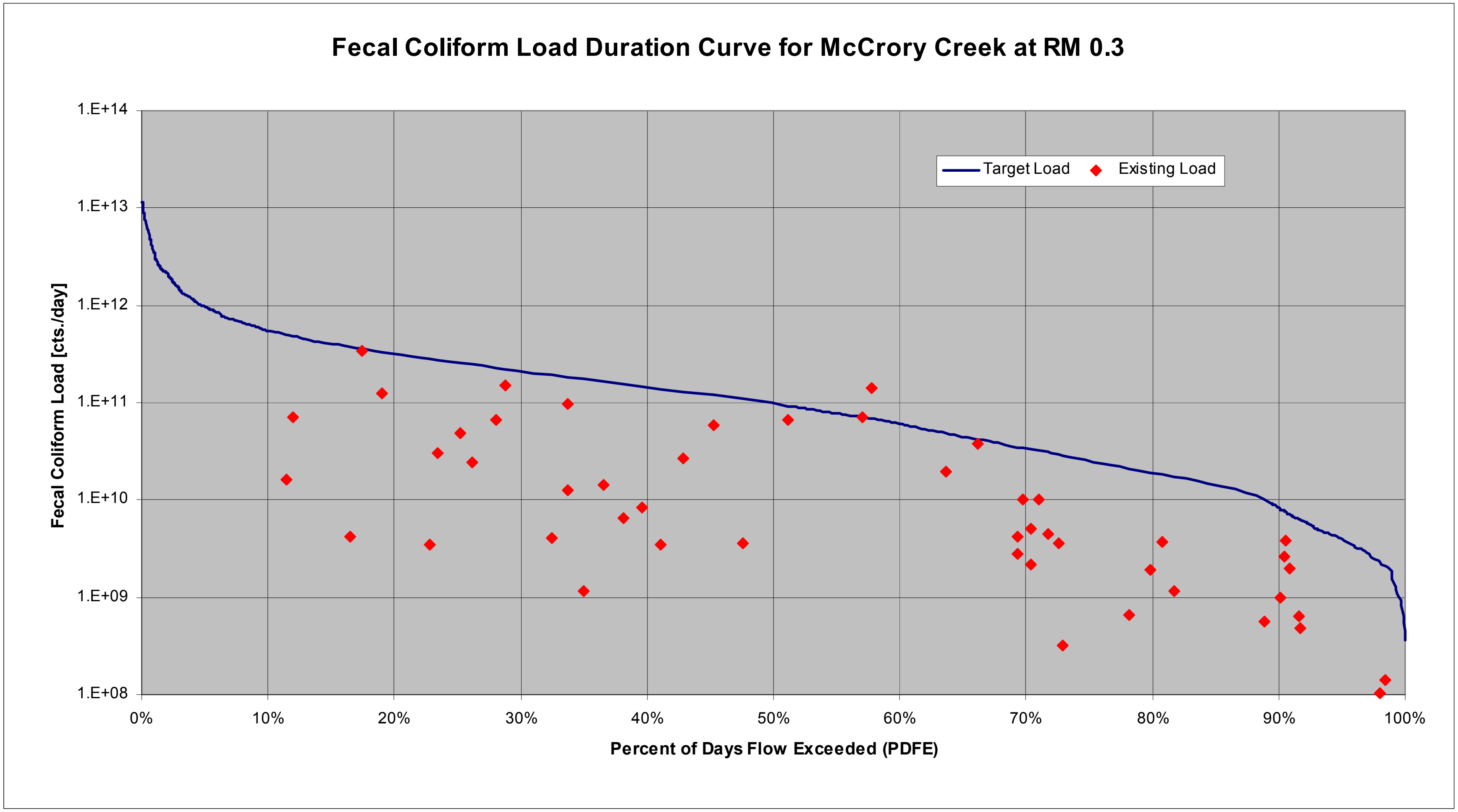


Figure C-4 Load Duration Curve for Christmas Creek at STORET Station CHRIS000.7RU

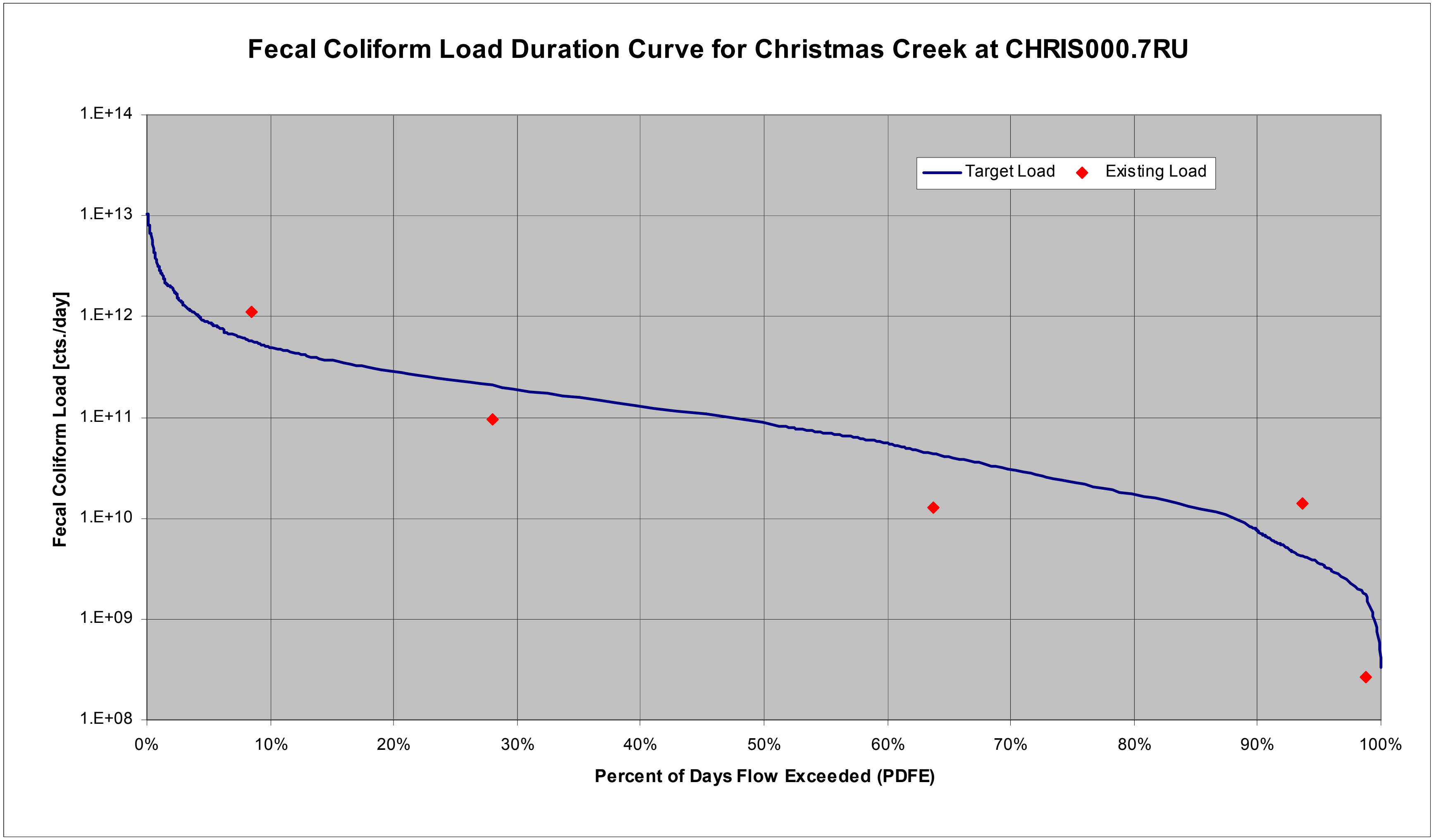


Table C-1 Determination of Required Load Reduction for Stoners Creek (RM 0.5)

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
4/3/96	78.124	11.4	100	1.912E+11	1.720E+12	NR
9/21/96	10.653	57.8	2,504	6.527E+11	2.346E+11	**64.1**
11/25/96	39.772	25.2	265	2.579E+11	8.758E+11	NR
3/30/00	19.886	42.9	8	3.893E+09	4.379E+11	NR
3/31/00	17.045	47.6	52	2.169E+10	3.754E+11	NR
4/6/00	44.033	22.8	520	5.603E+11	9.697E+11	NR
4/7/00	34.090	28.8	113	9.426E+10	7.507E+11	NR
4/10/00	26.988	35.0	15	9.905E+09	5.943E+11	NR
4/18/00	28.409	33.7	25	1.738E+10	6.256E+11	NR
4/20/00	22.727	39.6	128	7.118E+10	5.005E+11	NR
4/27/00	75.283	12.0	210	3.868E+11	1.658E+12	NR
4/30/00	42.613	23.4	30	3.128E+10	9.384E+11	NR
5/1/00	35.511	28.0	30	2.607E+10	7.820E+11	NR
5/2/00	28.409	33.7	59	4.101E+10	6.256E+11	NR
5/3/00	55.397	17.4	113	1.532E+11	1.220E+12	NR
5/31/00	18.466	45.3	60	2.711E+10	4.066E+11	NR
6/1/00	14.204	51.2	140	4.866E+10	3.128E+11	NR
6/2/00	11.079	57.0	90	2.440E+10	2.440E+11	NR
6/5/00	7.528	63.7	80	1.474E+10	1.658E+11	NR
6/6/00	6.534	66.2	70	1.119E+10	1.439E+11	NR
6/7/00	5.398	69.3	43	5.679E+09	1.189E+11	NR
6/8/00	5.114	70.4	40	5.005E+09	1.126E+11	NR
6/9/00	4.545	72.6	55	6.117E+09	1.001E+11	NR
6/12/00	2.841	80.8	41	2.850E+09	6.256E+10	NR
6/13/00	2.699	81.7	93	6.141E+09	5.943E+10	NR
7/11/00	1.094	90.9	118	3.158E+09	2.409E+10	NR
7/13/00	1.179	90.4	169	4.875E+09	2.596E+10	NR
7/14/00	0.810	92.8	270	5.349E+09	1.783E+10	NR
7/18/00	0.355	98.0	98	8.515E+08	7.820E+09	NR
8/2/00	4.972	71.0	230	2.798E+10	1.095E+11	NR
8/7/00	1.562	88.9	224	8.564E+09	3.441E+10	NR
8/8/00	1.165	90.5	290	8.265E+09	2.565E+10	NR
8/10/00	0.980	91.6	2,890	6.931E+10	2.158E+10	**68.9**
8/15/00	0.327	98.4	270	2.158E+09	7.194E+09	NR
1/8/01	5.256	69.8	30	3.858E+09	1.157E+11	NR
1/9/01	4.829	71.7	148	1.749E+10	1.064E+11	NR
1/10/01	4.403	72.9	1	1.077E+08	9.697E+10	NR
1/15/01	5.398	69.3	92	1.215E+10	1.189E+11	NR
1/16/01	5.114	70.4	51	6.381E+09	1.126E+11	NR
1/22/01	51.136	19.0	94	1.176E+11	1.126E+12	NR
1/23/01	38.352	26.2	52	4.880E+10	8.446E+11	NR
1/24/01	29.829	32.5	16	1.168E+10	6.569E+11	NR
1/25/01	24.147	38.1	18	1.064E+10	5.318E+11	NR
1/26/01	21.307	41.1	26	1.355E+10	4.692E+11	NR
3/1/01	58.238	16.5	30	4.275E+10	1.282E+12	NR
6/25/01	2.983	79.8	193 *	1.409E+10	6.569E+10	NR
10/30/01	3.267	78.2	160	1.279E+10	7.194E+10	NR
2/18/02	19.886	42.9	155 *	7.542E+10	4.379E+11	NR
5/23/02	25.568	36.6	110	6.882E+10	5.630E+11	NR
8/12/02	1.264	90.1	210	6.496E+09	2.784E+10	NR

Note: NR = Not Required
* Value is geometric means of multiple samples collected on date indicated.

Table C-2 Determination of Required Load Reduction for McCrory Creek (RM 0.3)

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Fecal Coliform Sample Load	Fecal Coliform Target Load	Fecal Coliform Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
4/3/96	22.869	11.4	29	1.623E+10	5.036E+11	NR
9/21/96	3.119	57.8	1,848	1.410E+11	6.868E+10	51.3
11/25/96	11.643	25.2	173	4.928E+10	2.564E+11	NR
3/31/00	4.990	47.6	29	3.541E+09	1.099E+11	NR
4/6/00	12.890	22.8	11	3.469E+09	2.839E+11	NR
4/7/00	9.979	28.8	620	1.514E+11	2.198E+11	NR
4/10/00	7.900	35.0	6	1.160E+09	1.740E+11	NR
4/18/00	8.316	33.7	61	1.241E+10	1.831E+11	NR
4/20/00	6.653	39.6	52	8.465E+09	1.465E+11	NR
4/27/00	22.038	12.0	130	7.010E+10	4.853E+11	NR
4/30/00	12.474	23.4	100	3.052E+10	2.747E+11	NR
5/1/00	10.395	28.0	260	6.613E+10	2.289E+11	NR
5/2/00	8.316	33.7	470	9.564E+10	1.831E+11	NR
5/3/00	16.216	17.4	860	3.412E+11	3.571E+11	NR
5/31/00	5.405	45.3	450	5.952E+10	1.190E+11	NR
6/1/00	4.158	51.2	650	6.613E+10	9.157E+10	NR
6/2/00	3.243	57.0	890	7.063E+10	7.142E+10	NR
6/5/00	2.204	63.7	360	1.941E+10	4.853E+10	NR
6/6/00	1.913	66.2	820	3.838E+10	4.212E+10	NR
6/7/00	1.580	69.3	110	4.253E+09	3.480E+10	NR
6/8/00	1.497	70.4	140	5.128E+09	3.296E+10	NR
6/9/00	1.331	72.6	110	3.581E+09	2.930E+10	NR
6/12/00	0.832	80.8	180	3.663E+09	1.831E+10	NR
6/13/00	0.790	81.7	60	1.160E+09	1.740E+10	NR
7/10/00	0.349	90.4	310	2.649E+09	7.692E+09	NR
7/11/00	0.320	90.9	250	1.959E+09	7.051E+09	NR
7/18/00	0.104	98.0	40	1.017E+08	2.289E+09	NR
8/2/00	1.455	71.0	280	9.971E+09	3.205E+10	NR
8/7/00	0.457	88.9	50	5.596E+08	1.007E+10	NR
8/8/00	0.341	90.5	460	3.838E+09	7.509E+09	NR
8/9/00	0.283	91.7	70	4.843E+08	6.227E+09	NR
8/10/00	0.287	91.6	90	6.318E+08	6.318E+09	NR
8/15/00	0.096	98.4	60	1.404E+08	2.106E+09	NR
1/8/01	1.538	69.8	270	1.016E+10	3.388E+10	NR
1/9/01	1.414	71.7	130	4.497E+09	3.113E+10	NR
1/10/01	1.289	72.9	10	3.154E+08	2.839E+10	NR
1/15/01	1.580	69.3	72	2.784E+09	3.480E+10	NR
1/16/01	1.497	70.4	60	2.198E+09	3.296E+10	NR
1/22/01	14.969	19.0	340	1.245E+11	3.296E+11	NR
1/23/01	11.227	26.2	90	2.472E+10	2.472E+11	NR
1/24/01	8.732	32.5	19	4.059E+09	1.923E+11	NR
1/25/01	7.069	38.1	38	6.573E+09	1.557E+11	NR
1/26/01	6.237	41.1	23	3.510E+09	1.374E+11	NR
3/1/01	17.048	16.5	10	4.171E+09	3.754E+11	NR
6/25/01	0.873	79.8	89	1.902E+09	1.923E+10	NR
10/30/01	0.956	78.2	28	6.552E+08	2.106E+10	NR
2/18/02	5.821	42.9	190	2.706E+10	1.282E+11	NR
5/23/02	7.485	36.6	78 *	1.428E+10	1.648E+11	NR
8/12/02	0.370	90.1	110 *	9.961E+08	8.150E+09	NR

Note: NR = Not Required
* Value is geometric means of multiple samples collected on date indicated.

Table C-3 Determination of Required Load Reduction for Christmas Creek

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Fecal Coliform Sample Load	Fecal Coliform Target Load	Fecal Coliform Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
1/11/00	9.379	28.0	420	9.638E+10	2.065E+11	NR
4/12/00	25.885	8.5	1,775	1.124E+12	5.700E+11	**49.3**
7/26/00	0.079	98.8	137	2.641E+08	1.735E+09	NR
10/19/00	0.191	93.6	3,020	1.414E+10	4.213E+09	**70.2**
5/2/01	1.988	63.7	260	1.265E+10	4.379E+10	NR

Note: NR = Not Required

APPENDIX D

Determination of WLAs & LAs

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or <u>other appropriate measure</u>.

In general, fecal coliform TMDLs in each impaired subwatershed, WLA terms include:

- $[\sum WLAs]_{WWTF}$ is the required load reduction associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds. Since NPDES permits for these facilities specify that treated wastewater must meet instream water quality standards at the point of discharge, no additional load reduction is required. WLAs for permitted discharges are equal to the product of the permit limit, design flow, and required unit conversion factor. SSOs are unpermitted discharges and are required to be eliminated.

- $[\sum WLAs]_{CAFO}$ is the load reduction required for all CAFOs in an impaired subwatershed. Since discharges from a CAFO liquid waste handling facility to waters of the state during a chronic or catastrophic rainfall event (in excess of a 25-year, 24-hour rainfall event), or as a result of an unpermitted discharge, upset, or bypass of the system, are not to cause or contribute to an exceedance of Tennessee water quality standards, a WLA = 0 is specified.

- $[\sum WLAs]_{MS4}$ is the required load reduction for discharges from MS4s. Fecal coliform loading from MS4s is the result of buildup/wash-off processes associated with storm events. The percent load reductions for MS4s are considered to be equal to the load reductions developed for TMDLs.

LA terms include::

- $[\sum LAs]_{DS}$ is the required reduction in fecal coliform loading from “other direct sources”. These sources include leaking septic systems, leaking collection systems, illicit discharges, and animals access to streams. For all sources of this type, the LA = 0.

- $[\sum LAs]_{SW}$ represents the required reduction in fecal coliform loading from nonpoint sources indirectly going to surface waters from all land use areas (except areas covered by a MS4 permit) as a result of the buildup/wash-off processes associated with storm events. The percent load reductions for precipitation-induced nonpoint sources are considered to be equal to the load reductions developed for TMDLs (and specified for MS4s).

Explicit MOS has already been incorporated into TMDL development as stated in Appendix B & Appendix C. WLAs & LAs for the McCrory Creek, Stoners Creek, and Christmas Creek drainage areas are summarized in Table D-1.

Table D-1 WLAs & LAs for Impaired Subwatersheds

Waterbody	WLAs				LAs	
	WWTFs		CAFOs	MS4s	Precipitation Induced Nonpoint Sources	Other Direct Sources
	M. Avg.	D. Max.				
	[cts/day]	[cts/day]	[cts/day]	[% Red.]	[% Red.]	[cts/day]
McCrory Creek	NA *	NA *	NA	68.8	68.8	0
Stoners Creek	NA *	NA *	NA	68.9	68.9	0
Christmas Creek	NA	NA	NA	70.2	70.2	0

Notes: TMDL = Percent load reduction specified for TMDL; NA = Not applicable.
* No permitted discharges from WWTFs in the drainage area. SSOs, which are unpermitted discharges associated with WWTF collection systems, contribute to pathogen impairment are required to be eliminated.

APPENDIX E

Sampling and Analysis of McCrory and Stoners Creek, 2000 - 2003

Sampling and Analysis of McCrory and Stoners Creeks, 2000 – 2003.

William P. Hamilton

Vanderbilt University, Nashville, Tennessee.

Introduction

Past studies of the Cumberland River near Nashville, Tennessee, by a team of investigators from Vanderbilt University, Consoer-Townsend-Envirodyne Engineers, Inc., and the Metro Nashville Department of Water and Sewerage Services have shown that there were significant violations of microbiological recreational water quality standards when rainfall exceeded 0.1 inch (1). Further study of the occurrence and fate of fecal coliform (FC) bacteria in the Cumberland River (9) found that, while large rainfall events (greater than 0.5 inch) produced FC densities in the range of 5,000 < FC < 25,000 CFU/100 mL, the effects were short-term and near field, and that densities of this magnitude would continue even if all combined sewer overflows (CSOs) were eliminated, since tributary streams were responsible for contributing nearly as much bacteria as CSOs. This finding prompted studies of the tributaries, which indicated that a great majority of the stream miles meet water quality standards during dry weather, yet all of the streams surveyed failed state standards during wet weather (5). With few exceptions, high FC densities could not be traced to separate sewer overflows.

Therefore, a project commenced to determine the sources of the bacteria in the streams that had high bacteria densities during dry weather and thus did not meet state standards. Determining the source of these bacteria would enable the appropriate corrective action to be specified in TMDL plans. This brief report summarizes the bacterial analysis and antibiotic resistance analysis (ARA) results that have been collected to date on McCrory Creek and Stoners Creek.

Method Description

Indicator bacteria was isolated and cultured using the appropriate media and techniques as outlined in *Standard Methods for the Examination of Water and Wastewater* (4). Bacterial densities were reported as colony forming units per 100 mL of sample (CFU/100 mL).

For antibiotic resistance analysis, a library of >2500 known source isolates from cow, deer, dog, horse, and human was constructed using established and accepted techniques (2, 3, 6-8, 10-13). Samples of all sources were collected from across Davidson County, Tennessee to insure representitiveness and minimize any impact of regionality.

Isolates from unknown sources (i.e., stream water samples) were subjected to the ARA assay, and the resulting antibiotic resistance patterns (ARPs) were analyzed by discriminant analysis to determine the probable source. Additional information regarding library development, the ARA assay, or the analysis of ARPs with discriminant analysis is available on request.

Results

McCrory Creek

McCrory Creek has been monitored extensively since 2000. During 2000, McCrory Creek at Stewarts Ferry Apartments (See Figure 1 for an explanation of site names and locations.), the most downstream site along the creek, was one of 13 sites in Davidson County subjected to intensive dry weather sampling for fecal coliforms. The results of this sampling suggested that McCrory Creek was not a chronic violator of state water quality standards: the geometric mean fecal coliform density for the 39 samples collected behind the Stewarts Ferry Apartments in 2000 was 120 CFU/100 mL, and none of the samples violated the state single sample maximum of 1000 CFU/100 mL.

Subsequent sampling from 2001 to the present has shown generally low bacterial densities (with periodic spikes that exceed the "typical" values). The geometric mean bacterial density for the samples collected on a quarterly basis (spring, summer, fall, winter) was below the state fecal coliform standard (150 CFU/100 mL) and at the state *E. coli* standard (130 CFU/100 mL). In addition, no violations of the state single sample fecal coliform criteria were observed since 2001, and only three violations of the proposed state single sample *E. coli* standard were observed.

In addition to routine quarterly monitoring, several surveys of the creek have been conducted in 2002 and in 2003 to attempt to determine the source of the periodic spikes in bacterial concentrations. The stream was segmented arbitrarily (Convenient access points were used to divide the stream-see Figure 1.), and samples were collected on several occasions to look for patterns in indicator densities. These surveys were not subject to the same strict dry weather criteria imposed on quarterly sampling (5 days of dry weather), so densities varied widely. However, the data collected to date suggest that the source of the bacteria is located below the Elm Hill Pike site, possibly in the branch that enters McCrory Creek between Elm Hill Pike and Boulder Park (heretofore referred to as "Elm Hill Branch"). Indeed, a survey of the area in 2003 revealed about 10 cows in the branch above the confluence with McCrory Creek (Figure 2).

Preliminary ARA suggests that the bacteria are from animal sources (Figure 3). ARA results from February 2003 found 67% of the 48 colonies isolated from behind the Stewarts Ferry Apartments were from animal sources. (Further speciation suggested that the bacteria was primarily dog.) ARA data from April 2003 found that samples collected from Elm Hill Pike, Ironwood, and behind the Stewarts Ferry Apartments were primarily animal (deer in all cases), while the sample from Stewarts Ferry Pike had a primarily human signature. Further investigation of the Elm Hill Branch is continuing to attempt to establish the sources in that reach.

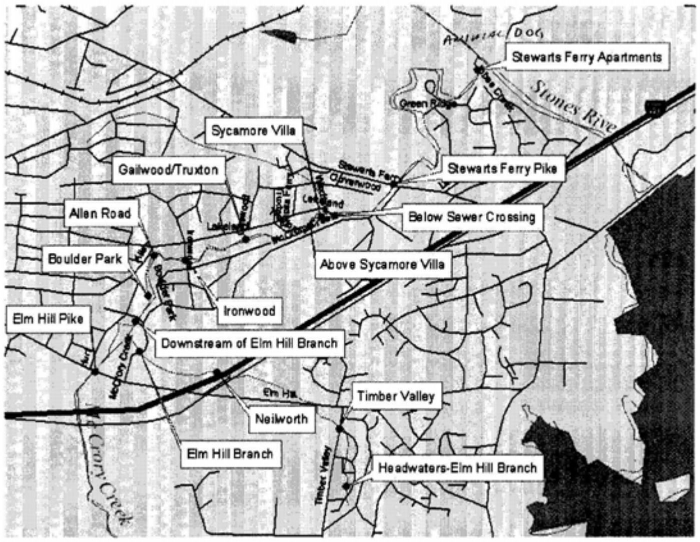


Figure 1: Location of Sampling Sites on McCrory Creek. See appendix for results.

Figure 2: Cows Observed Along Elm Hill Branch (Tributary of McCrory Creek).

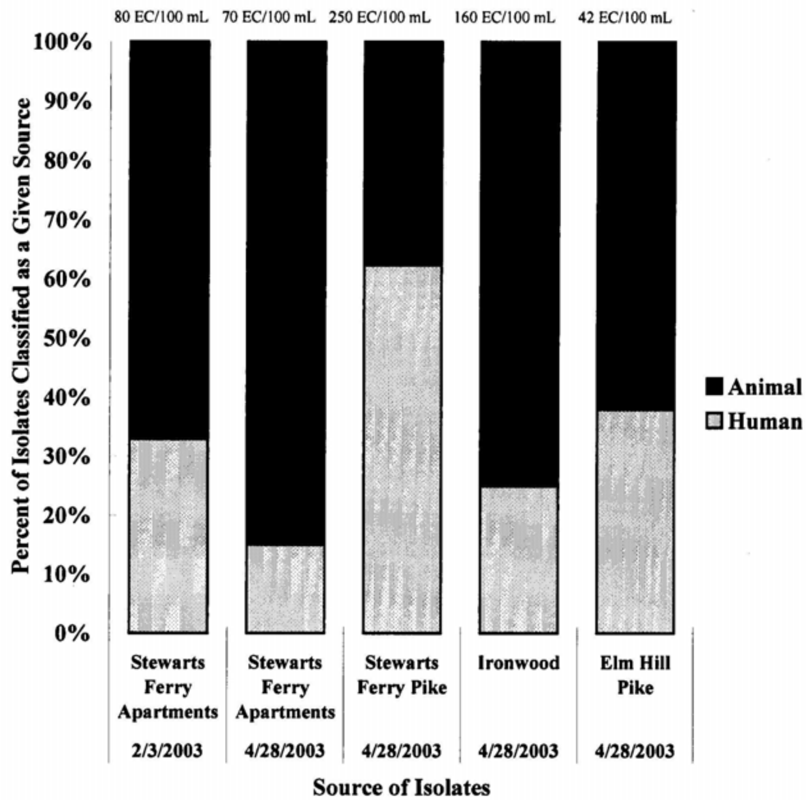


Figure 3: Classification of Isolates from Sites on McCrory Creek by ARA. (See Figure 1 for site locations and the appendix for complete bacterial densities.)

Stoners Creek

Stoners Creek has also been intensively surveyed since 2000. During 2000, Stoners Creek at Brandau Road (Figure 4) was one of 13 sites in Davidson County subjected to intensive dry weather sampling for fecal coliform. The results of this sampling suggested that Stoners Creek was not a chronic violator of state water quality standards; in fact, it was argued that Stoners Creek did not violate either state standard at all during 2000. But for a single, anomalous measurement of 2900 CFU/100 mL, which caused a violation of the single sample maximum fecal coliform standard and the state geometric mean standard, densities on Stoners Creek were consistently below both state fecal coliform standards. The geometric mean fecal coliform density for the 40 samples collected at Brandau Road in 2000 was 69 CFU/100 mL, and (but for the anomalous measurement of 2900 CFU/100 mL) none of the samples violated the state single sample maximum of 1000 CFU/100 mL.

Subsequent sampling from 2001 to the present has shown consistently low bacterial densities. The geometric mean bacterial density for the samples collected on a quarterly basis since 2001 are below the state fecal coliform standard (130 CFU/100 mL vs. the state standard of 200 CFU/100 mL) and the state *E. coli* standard (110 CFU/100 mL vs. the state standard of 130 CFU/100 mL). In addition, there has not been a single observed violation of either the state fecal coliform or (proposed) *E. coli* single sample criteria since 2001.

Because of the consistently low bacterial densities observed on Stoners Creek, only a single survey of Stoners Creek has been conducted (April 2003). Samples were collected at 4 points along the creek between Tulip Grove Road (upstream) and Brandau Road (downstream). Samples from each of these sites indicated low densities of both fecal coliform and *E. coli*. A survey of the watershed revealed a horse boarding facility as a potential source along the stream (Figure 5), but indicator densities suggest any impact from this facility (or any other source in the watershed) is minimal.

Results of preliminary ARA (Figure 6) indicate that the bacteria in this stream are overwhelmingly animal, with deer the primary source. More than 75% of the bacteria assayed in this watershed exhibited an animal signature.

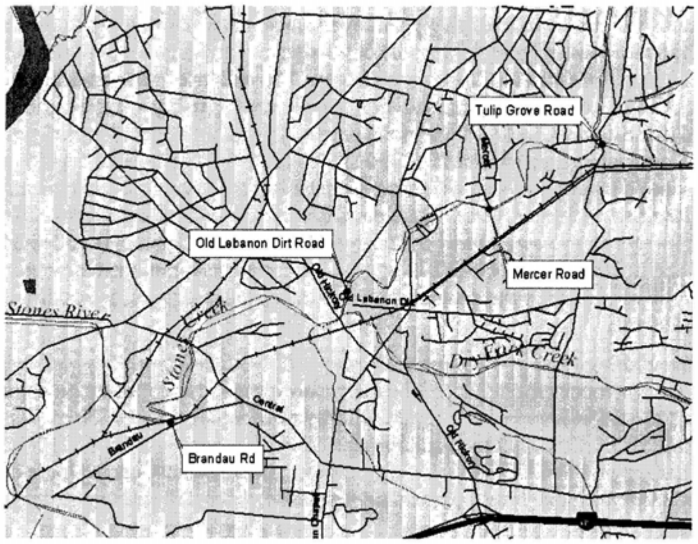


Figure 4: Location of Sampling Sites on Stoners Creek. See appendix for results.

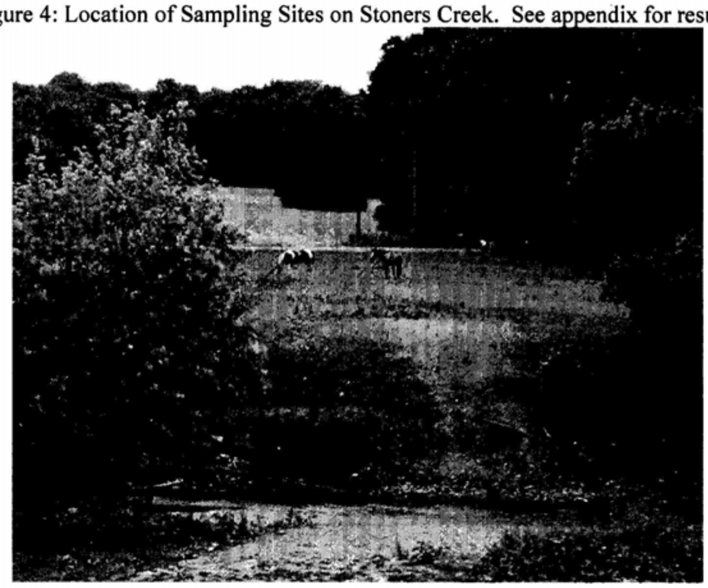


Figure 5: Horses Along Stoners Creek near Old Hickory Blvd and Old Lebanon Dirt Road.

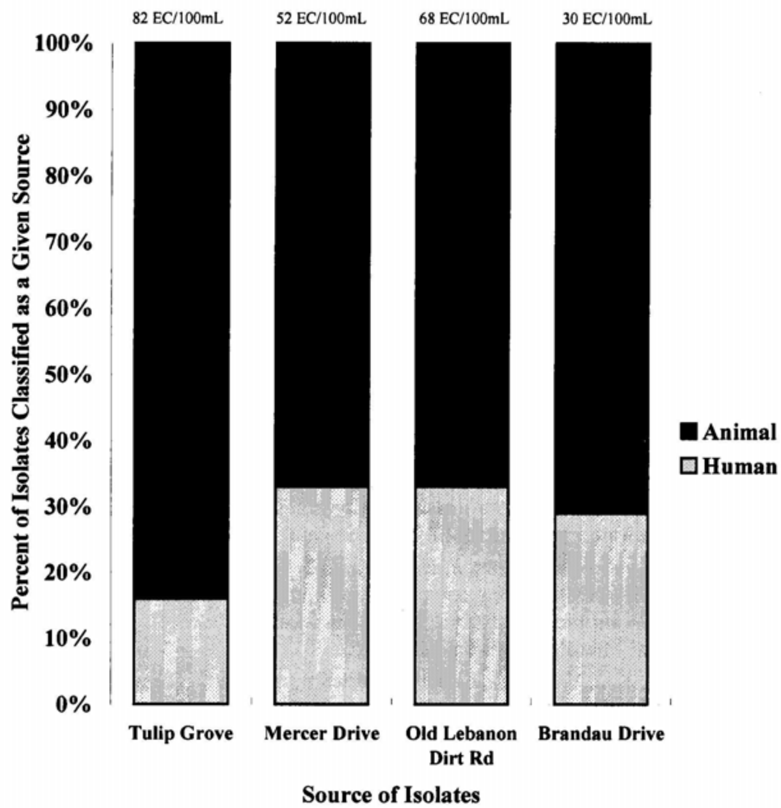


Figure 6: Classification of Isolates from Sites on Stoners Creek by ARA. (See Figure 4 for site locations and the appendix for complete bacterial densities.)

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Appendix:

Bacterial Data and ARA Data
from
McCrory Creek and Stoners Creek

Table A1: Quarterly Sampling Data for McCrory Creek, 2001 - present

Date	Stream Segment	Fecal Coliform[a]	Fecal Streptococcus[a]	E. Coli[a]	Enterococci[a]	FC/FS	E.Coli/FC	E.Coli/Ent	Ent/FS
	SEE TABLE A3 FOR 2000 10X DATA (FC ONLY)								
Mar-01	McCrory Creek								
	Stewarts Ferry Pike (1.3)	150	100	180	72	1.50	1.20	2.50	0.72
	Elm Hill Pike (4.1)	40	50	25	23	0.80	0.63	1.09	0.46
Jun-01	McCrory Creek								
	Stewarts Ferry Apts (0.3)	89	350	47	490	0.25	0.53	0.10	1.40
	Stewarts Ferry Pike (1.3)	940	490	490	580	1.92	0.52	0.84	1.18
	Stewart's Ferry (Metro)	650	290	270	--	2.24	0.42	--	--
	Elm Hill Pike (4.1)	320	760	280	1200	0.42	0.88	0.23	1.58
Nov-01	McCrory Creek								
	Stewarts Ferry Apts (0.3)	28	140	37	66	0.20	1.32	0.56	0.47
	Stewarts Ferry Pike (1.3)	150	240	160	320	0.63	1.07	0.50	1.33
	Elm Hill Pike (4.1)	34	80	20	65	0.43	0.59	0.31	0.81
Feb-02	McCrory Creek								
	@ Stewarts Ferry Apts (0.3)	190	140	290	120	1.36	1.53	2.42	0.86
	@ Stewarts Ferry Pike (1.3)	210	140	260	99	1.50	1.24	2.63	0.71
	@ Stewarts Ferry Pike (1.3)	200	160	260	88	1.25	1.30	2.95	0.55
	@ Elm Hill Pike (4.1)	90	32	82	30	2.81	0.91	2.73	0.94
May-02	McCrory Creek								
	@ Stewarts Ferry Apts (0.3)	82	60	57	45	1.37	0.70	1.27	0.75
	@ Stewarts Ferry Apts (0.3)	75	--	24	83	--	0.32	0.29	--
	@ Stewarts Ferry Pike (1.3)	660	450	816	1733	1.47	1.24	0.47	3.85
	@ Elm Hill Pike (4.1)	85	82	63	150	1.04	0.74	0.42	1.83
Aug-02	McCrory Creek								
	@ Stewarts Ferry Apts (0.3)	110	350	93	920	0.31	0.85	0.10	2.63
	@ Stewarts Ferry Apts (D)	110	550	78	870	0.20	0.71	0.09	1.58
	@ Stewarts Ferry Pike (1.3)	220	400	180	1700	0.55	0.82	0.11	4.25
	@ Elm Hill Pike (4.1)	410	510	170	2400	0.80	0.41	0.07	4.71
Oct-02	McCrory Creek								
	@ Stewarts Ferry Apartments	320	230	370	580	1.39	1.16	0.64	2.52
Jan-03	McCrory Creek								
	@ Stewarts Ferry Apartments	--	--	61	20	--	--	3.1	--
Feb-03	McCrory Creek								
	@ Stewarts Ferry Apartments	110	54	80	26	2.0	3.1	0.7	0.5
Apr-03	McCrory Creek								
	@ Stewarts Ferry Apartments	--	--	770	> 2400	--	--	< 0.32	--
	@ Stewarts Ferry Pike	--	--	980	> 2400	--	--	< 0.41	--
	@ Elm Hill Pike	--	--	60	21	--	--	2.9	--

a results for fecal coliform, E. coli, fecal strep and enterococcus in CFU/100 mL

Table A2: Quarterly Sampling Data for Stoners Creek, 2001 – present.

Date	Stream Segment	Fecal Coliform[a]	Fecal Streptococcus[a]	E. Coli[a]	Enterococci[a]	FC/FS	E.Coli/FC	E.Coli/Ent	Ent/FS
	SEE TABLE A3 FOR 10X DATA (FC ONLY)								
Mar-01	Stoners Creek								
	Brandau Road (0.5)	30	180	10	7	0.17	0.33	1.43	0.04
	Old Lebanon Dirt Road (2.1)	180	200	390	190	0.90	2.17	2.05	0.95
Jun-01	Stoners Creek								
	Brandau Road (0.5)	170	96	100	180	1.77	0.59	0.56	1.88
	Brandau Road (Metro)	220	480	180	--	0.46	0.82	--	--
	Old Lebanon Dirt Road (2.1)	180	130	130	550	1.38	0.72	0.24	4.23
Nov-01	Stoners Creek								
	Brandau Road (0.5)	160	170	120	160	0.94	0.75	0.75	0.94
	Old Lebanon Dirt Road (2.1)	58	150	46	240	0.39	0.79	0.19	1.60
Feb-02	Stoners Creek								
	@ Brandau Road (0.5)	160	170	170	170	0.94	1.06	1.00	1.00
	@ Brandau Road (0.5)[b]	150	160	200	190	0.94	1.33	1.05	1.19
	@ Old Lebanon Dirt Road (2.1)	130	52	100	31	2.50	0.77	3.23	0.60
May-02	Stoners Creek								
	@ Brandau Road (0.5)	110	180	170	310	0.61	1.55	0.55	1.72
	@ Old Lebanon Dirt Road (2.1)	240	150	330	390	1.60	1.38	0.85	2.60
	@ Old Lebanon Dirt Road (2.1)	330	--	260	250	--	1.00	1.32	--
Aug-02	Stoners Creek								
	@ Brandau Road (0.5)	210	300	89	290	0.70	0.42	0.31	0.97
	@ Old Lebanon Dirt Road (2.1)	82	340	93	580	0.24	1.13	0.16	1.71
Oct-02	Stoners Creek								
	@ Brandau Road (0.5)	150	220	200	600	0.68	1.33	0.33	2.73
Jan-03	Stoners Creek								
	@ Brandau Road (0.5)	--	--	47	13	--	--	3.62	--
Feb-03	Stoners Creek								
	@ Brandau Road	28	80	26	20	0.4	1.3	0.9	0.3
Apr-03	Stoners Creek								
	@ Brandau Road (0.5)	--	--	96	170	--	--	0.56	--
	@ Tulip Grove Road	--	--	62	32	--	--	1.9	--

a results for fecal coliform, E. coli, fecal strep and enterococcus in CFU/100 mL

Table A3: Sampling Data for McCrory and Stoners Creeks, 2000.

McCrory Creek 2000		Stoners Creek 2000	
Date	FC (CFU/100 mL)	Date	FC (CFU/100 mL)
3/31/2000	29	3/30/1999	8
4/6/1999	11	3/31/2000	52
4/7/1999	620	4/6/1999	520
4/10/1999	6	4/7/1999	110
4/18/2000	61	4/10/1999	15
4/20/2000	52	4/18/2000	25
4/27/2000	130	4/20/2000	130
4/30/2000	100	4/27/2000	210
5/1/2000	260	4/30/2000	30
5/2/2000	470	5/1/2000	30
5/3/2000	860	5/2/2000	59
5/31/2000	450	5/3/2000	110
6/1/2000	650	5/31/2000	60
6/2/2000	890	6/1/2000	140
6/5/2000	360	6/2/2000	90
6/6/2000	820	6/5/2000	80
6/7/2000	110	6/6/2000	70
6/8/2000	140	6/7/2000	43
6/9/2000	110	6/8/2000	40
6/12/2000	180	6/9/2000	55
6/13/2000	60	6/12/2000	41
7/10/2000	310	6/13/2000	93
7/11/2000	250	7/11/2000	120
7/18/2000	40	7/13/2000	170
8/2/2000	280	7/14/2000	270
8/7/2000	50	7/18/2000	98
8/8/2000	460	8/2/2000	230
8/9/2000	70	8/7/2000	220
8/10/2000	90	8/8/2000	290
1/8/2001	270	8/10/2000	2900
1/9/2001	130	1/8/2001	30
1/10/2001	10	1/9/2001	150
1/15/2001	72	1/10/2001	1
1/16/2001	60	1/15/2001	92
1/22/2001	340	1/16/2001	51
1/23/2001	90	1/22/2001	94
1/24/2001	19	1/23/2001	52
1/25/2001	38	1/24/2001	16
1/26/2001	23	1/25/2001	18
		1/26/2001	26

Table A4: Site Surveys of McCrory Creek, 2002.

SiteName	*E coli*		Enterococci		EC/Ent	Comments
6/11/2002 Elm Hill Pike	240		390		0.62	Low flow/depth
6/11/2002 West of Boulder Park	180		390		0.46	Low flow/depth
6/11/2002 Ironwood Drive	360		1100		0.33	Low flow/depth
6/11/2002 Sycamore Villa	770	>	2400	<	0.32	
6/11/2002 Below Sewer Crossing	460		2400		0.19	Low flow/depth
6/11/2002 Stewarts Ferry Pike	610		1200		0.51	rain 5 days prior

SiteName	*E coli*	Enterococci	EC/Ent	Comments
6/17/2002 Elm Hill Pike	170	420	0.40	Low depth/flow. Depth ~ 6 in
6/17/2002 Ironwood Drive	820	650	1.26	Low depth/flow. Depth ~ 8 in
6/17/2002 Truxton/Gailwood	1400	1300	1.08	Low flow/depth. Depth ~ 10 in
6/17/2002 Above Sycamore Villa	1300	1600	0.81	Low flow/depth. Depth ~ 10 in
6/17/2002 Below Sewer Crossing	1200	1200	1.00	Low flow/depth. Depth ~ 10 in
6/17/2002 Stewarts Ferry Pike	280	730	0.38	Depth ~ 12 in
				rain 4 days prior

SiteName	*E coli*		Enterococci		EC/Ent	Comments
6/26/2002 Elm Hill Pike	462		1400		0.33	
6/26/2002 West of Boulder Park	1200		3000		0.40	
6/26/2002 Ironwood Drive	2600		4000		0.65	
6/26/2002 Truxton/Gailwood	4000	>	4800	<	0.83	
6/26/2002 Above Sycamore Villa	3000		4800		0.63	
6/26/2002 Stewarts Ferry Pike	2800	>	4800	<	0.58	
6/26/2002 Elm Hill Branch	4800		4800		1.00	both values exceeded detection limit
6/26/2002 DS Elm Hill Branch	820		2400		0.34	
						rain 1 day prior

Table A5: Site Surveys of McCrory Creek, 2003.

Date	SiteName	*E coli*	Enterococci	EC/Ent	Comments
4/28/2003	Stewarts Ferry Apartments	70	250	0.28	backwater conditions at StFApts
4/28/2003	Stewarts Ferry Pike	250	550	0.45	
4/28/2003	Ironwood	160	920	0.17	Rain Apr 25 (0.25") and 26 (0.16")
4/28/2003	Elm Hill Pike	42	35	1.2	
		FC	**FS**	**FC/FS**	**Comments**
4/28/2003	Stewarts Ferry Apartments	80	760	0.11	backwater conditions at StFApts
4/28/2003	Stewarts Ferry Pike	294	910	0.32	
4/28/2003	Ironwood	200	1200	0.17	Rain Apr 25 (0.25") and 26 (0.16")
4/28/2003	Elm Hill Pike	92	72	1.3	

Date	SiteName	*E coli*	Enterococci	EC/Ent	Comments
5/1/2003	Elm Hill Pike	110	190	0.58	
5/1/2003	Below Elm Hill Branch	1600	> 2400	< 0.67	Rain Apr 25 (0.25") and 26 (0.16")
5/1/2003	Boulder Park	230	520	0.44	
5/1/2003	Allen Road	550	1600	0.34	
5/1/2003	Ironwood	370	820	0.45	
5/1/2003	Elm Hill Branch at Confl.	7700	9200	0.84	Cows seen above sampling site

Date	SiteName	*E coli*	Enterococci	EC/Ent	Comments
5/28/2003	McCrory Creek Road	500	> 2400	< 0.21	
5/28/2003	Neilworth	380	> 2400	< 0.16	Slight rain May 26 (0.25")
5/28/2003	S. TimberValley	560	2000	0.28	

Date	SiteName	*E coli*	Enterococci	EC/Ent	Comments
5/30/2003	Headwaters of Elm Hill Br.	14	63	0.22	Slight rain May 29 (0.07")

Table A6: Site Survey of Stoners Creek, 2003.

Date	Site	FC	EC	FS	Ent	FC/FS	EC/Ent
4/28/2003	Tulip Grove	110	82	100	38	1.1	2.2
4/28/2003	Mercer Drive	74	52	82	39	0.90	1.33
4/28/2003	Old Lebanon Dirt Rd	78	68	130	75	0.60	0.91
4/28/2003	Brandau Drive	58	30	400	140	0.15	0.21

Table A7: ARA Results for McCrory Creek, 2003.

Date	Site	n	Human	Animal	Dog	Deer	Human	Livestock
2/3/2003	Stewarts Ferry Apartments	48	33	67	62	3	30	5
	Density data in Table A1							

Date	Site	n	Human	Animal	Dog	Deer	Human	Livestock
4/28/2003	Stewarts Ferry Apartments	27	15	85	7	78	15	0
4/28/2003	Stewarts Ferry Pike	48	***63***	***38***	--	--		--
4/28/2003	Ironwood	48	25	75	32	50	8	10
4/28/2003	Elm Hill Pike	21	38	62	0	81	19	0
	Density data found in Table A5							

Table A8: ARA Results for Stoners Creek, 2003.

Date	Site	n	Human	Animal	Dog	Deer	Human	Livestock
4/28/2003	Tulip Grove	44	16	84	3	86	11	0
4/28/2003	Mercer Drive	24	33	67	29	54	13	4
4/28/2003	Old Lebanon Dirt Rd	40	33	67	3	55	28	15
4/28/2003	Brandau Drive	24	29	71	33	54	13	0

Density data found in Table A6

APPENDIX F

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR FECAL COLIFORM IN CHRISTMAS CREEK McCRORY CREEK STONERS CREEK STONES RIVER WATERSHED (HUC 05130203), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Loads (TMDLs) for fecal coliform for several waterbodies in the Stones River watershed located in middle Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

Christmas Creek, McCrory Creek, and Stoners Creek are listed on Tennessee's final 1998 303(d) list or final 2002 303(d) as not supporting designated use classifications due, in part, to pathogens associated with urban storm water runoff, storm sewer systems, collection system failure, and agriculture. The TMDLs utilize Tennessee's general water quality criteria, USGS continuous record station flow data, in-stream water quality monitoring data, a calibrated dynamic water quality model, load duration curves, and an appropriate Margin of Safety (MOS) to establish reductions in fecal coliform loading which will result in lower in-stream concentrations and the attainment of water quality standards. The TMDLs require reductions in in-stream fecal coliform loading of approximately 70% in the three listed waterbodies.

The proposed fecal coliform TMDLs may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/proposed.php

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Bruce R. Evans, P.E., Watershed Management Section
Telephone: 615-532-0668

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the TMDLs are invited to submit their comments in writing no later than April 22, 2004 to:

Division of Water Pollution Control
Watershed Management Section
6th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.

APPENDIX G

Public Comments Received

Comments received from Metro Water Services

Metropolitan Nashville Department of Water and Sewerage Services
Comments & Questions Concerning
Proposed Fecal Coliform Total Maximum Daily Load (TMDL)
For
McCrory Creek, Stoners Creek and Christmas Creek

The Department of Water and Sewerage Services of the Metropolitan Government of Nashville and Davidson County Tennessee (Metro) submits the following comments on the draft report entitled *Proposed Total Maximum Daily Load (TMDL) for Fecal Coliform in McCrory Creek, Stoners Creek, and Christmas Creek*.

We appreciate the opportunity to comment and will work cooperatively with the Tennessee Department of Environment and Conservation (TDEC) to improve water quality in the two creeks reported on in this document and in all other streams within Metro.

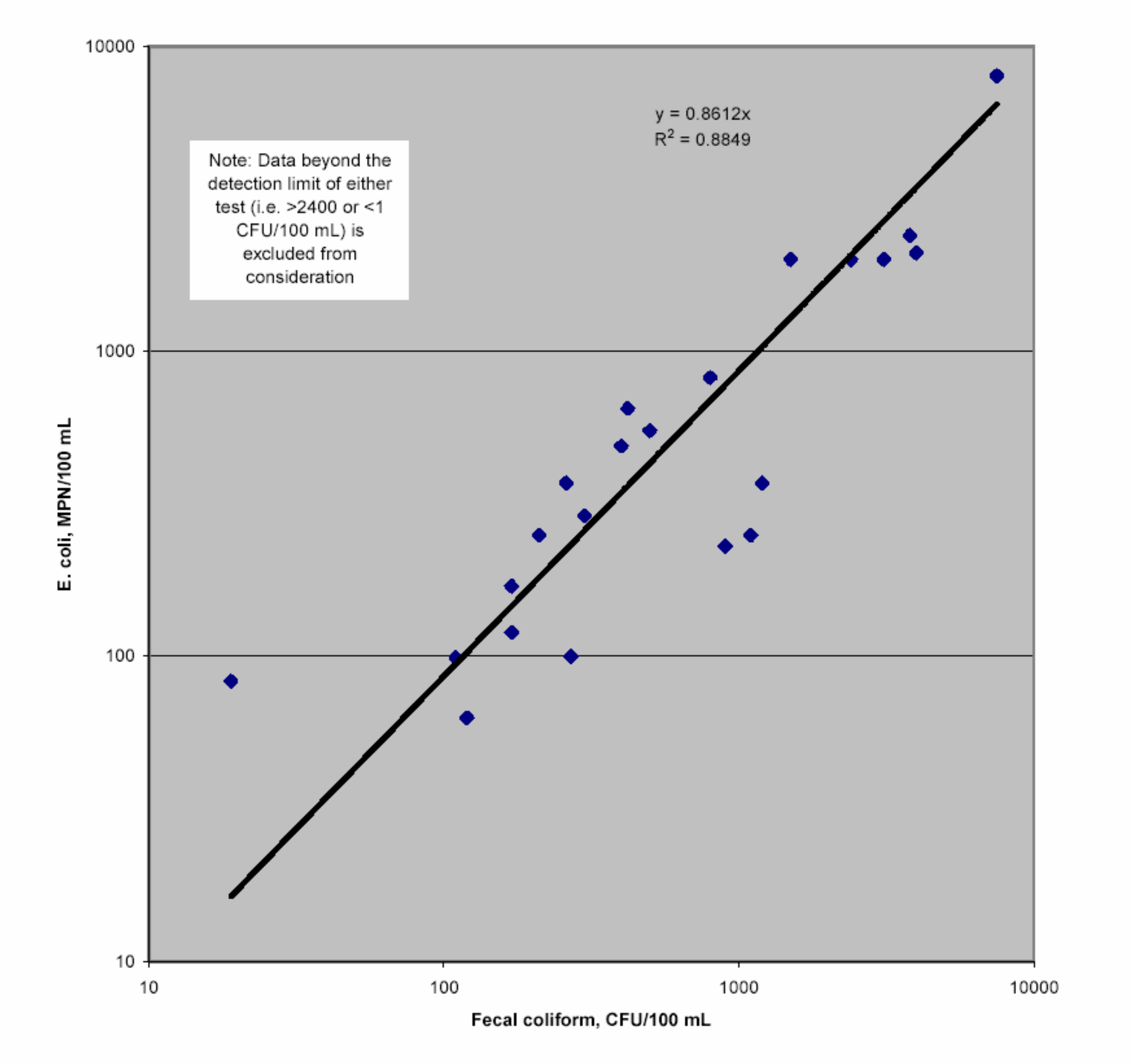
In general, we believe that the TMDL report is well-written, comprehensive, and easily read and understood. There are relatively few grammatical errors and only one major technical error. Although we question some of the assumptions and judgments, we recognize that many assumptions and judgments always have to be made in a study such as this, and reasonable people will make different choices. We have attached copies of the pages on which we found and marked grammatical or punctuation errors, but will not discuss them in this letter. We will point out the technical error. Listed below are our detailed comments.

<u>The need for the TMDL</u>

1. The analytical data referenced within the TMDL show an extremely high percentage of values in compliance with state fecal coliform (FC) limits. Given this fact, what data necessitated placing the McCrory Creek and Stoners Creek segments on the TDEC 2002 303(d) list as "not fully supportive," thereby requiring a TMDL on these segments for FC?

<u>The use of fecal coliform vs. *Escherichia coli* as indicator organisms</u>

2. On page 10, we note that the TMDL analysis is based on the former FC criteria. We believe there are enough data available based on the new *E. coli* criteria to base the TMDL analysis on those data, and think that the results would have been more meaningful. As has been done in other TMDLs, TDEC could have used a conversion factor to estimate *E. coli* densities from FC data when FC data were unavailable. For example, on page 12, we note that there are a number of pairs of FC and *E. coli* data obtained from TDEC from the three creeks discussed in this report. We have analyzed these data and found that they are highly correlated ($r = 0.94$), with the *E. coli* density averaging 86% of the FC density. This observation is consistent with those of Noble et al. (*Water Research*, 38 (2004) 1183-1188) and Hamilton et al. (*Water Research*, in press), who found that *E. coli* densities comprise approximately 88% and 81%, respectively, of the thermo-tolerant FC density in coastal and fresh waters. In addition, the TMDL for Lower Geddes Pond, Michigan (page 2-14 of *Protocol for Developing Pathogen TMDLs*, (first ed.) Office of Water, U.S. Environmental Protection Agency, Washington DC, EPA 841-R-00-002) found that 76% of the FC cultured during wet weather were *E. coli*.



<u>Stream segments to which the TMDLs apply</u>

3. As is stated in Tables 2 and 3 on page 7, large segments of Stoners Creek and McCrory Creek were removed from the 303(d) list between 1998 and the 2002. Therefore, a TMDL is only necessary for the segments that remain on the list. No statement is made in the document that identifies the portion of each stream to which the proposed TMDL will apply. Will the TMDL apply to only the portion of each stream included on the 2002 303(d) list? If not, why not?

4. With regards to Item 3, it should be noted that only the lower 0.3 miles of McCrory Creek are on the 2002 section 303(d) list, and thus the TMDL only applies to the 0.3 miles downstream of the McCrory Creek pumping station. All of the 10-times-per-month samples on which the required pollutant reduction calculations are based were taken downstream of the McCrory Creek pumping station. We do not believe that McCrory Creek has a consistent, endemic FC problem, but only sporadic high counts, likely due to bypasses at the pumping station. This is illustrated by the fact that McCrory Creek failed the 10-sample average only once, with a geometric mean of 260 CFU/100 mL; while the other 10-sample averages were much lower (110 and 62 CFU/100 mL). We also note that the set that failed the standard was taken immediately after a very high flow spike on the hydrograph, when the pumping station was probably

bypassing, and the counts generally declined during the sampling period. If pumping station bypasses are the only significant source of FCs, then requiring a specific percent reduction based only on one set of data obscures the problem. In these cases, requiring a percent reduction is meaningless. What should be required is the elimination of bypasses, which would be a 100% reduction of the only major source. This comment also applies to Stoners Creek, as noted in comment number 12.

Margin of Safety

5. On page 22, we question whether it is necessary to use both an implicit *and* explicit margin of safety (MOS). According to EPA, "The margin of safety is traditionally either implicitly accounted for by choosing conservative assumptions about loading and/or water quality response, *or* [emphasis added] is explicitly accounted for during the allocation of loads" [1]. If extremely conservative assumptions are implicit in the modeling exercise, such as assuming septic systems discharging directly into streams, no die-off of coliform deposited to the land, and 45 deer per square mile, we do not believe it should be necessary to additionally use an explicit MOS (lowering the target FC criteria to 180 CFU/100 mL). Lowering the target to 180 CFU/100 mL would be reasonable for comparing actual measurements to a standard, but we do not believe it is justified in the modeling, where extremely conservative assumptions have already been made. This practice could theoretically result in a TMDL being significantly lower than the allowable Water Quality Standard value. It should be noted that the Case Study TMDL provided in the EPA guidance *Protocol for Developing Pathogen TMDLs* uses only an explicit MOS for modeling purposes, and that other FC TMDLs proposed by TDEC have used only one MOS2 (i.e. "implicit" MOS[2] used in the Roan Creek TMDL).

Data age limits for assessment and TMDL development

6. In the TDEC 2002 303(d) list in the "What's new for 2002" section's "Higher Degree of Confidence" verbiage, using *recently* collected *data* was mentioned as an improvement over past 303(d) lists. How was the determination made that 1996 data was to be used as part of the formulation of this particular TMDL? What is the data age limit for water quality data used in 303(d) list stream assessments? What is the age limit for water quality data used to formulate TMDLs?

Stormwater issues

7. Although individual NPDES permit loading contributions were mentioned, how are the loading contributions of the various TDEC WPC-issued General NPDES Permit sites (construction, industrial, etc.) considered in the formulation of a TMDL?

8. Since MS4s (7.1.2) often discharge runoff from areas that would be considered to have bacterial loading due to wildlife, agricultural animals, and failing septic systems (7.2.1., 7.2.2., and 7.2.3., respectively), how is that accounted for in the formulation of a TMDL's WLAs? For example, if a cow pasture's runoff drains eventually into an MS4 (as many do), is that counted as part of the MS4's WLA? Given that situation, in consideration of any high FC levels that might be found in these stream segments in the future; how does TDEC, plan to definitively differentiate contribution sources in order to determine if respective TMDL responsibilities have been fulfilled?

1 *Protocol for Developing Pathogen TMDLs*, (first ed.) Office of Water U.S. Environmental Protection Agency, Washington DC, EPA 841-R-00-002

2 Total Maximum Daily Load for Fecal Coliform in Roan Creek, including Forge Creek and Town Creek Watauga River Watershed, Tennessee (HUC 06010103), Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Watershed Management Section, Nashville, TN. January 30, 2001.

9. On pages 25 and 26, the report lists a number of steps that Metro should take to achieve compliance with the standard. We note, however, that many of the proposed remedies are not applicable to McCrory Creek or Stoners Creek, which have no municipal or industrial discharges in Metro, and many have no influence on FC, which is the only pollutant analyzed in this report. The inclusion of these irrelevant items seems confusing and distracting.

10. With regard to item 9, since MS4s receive storm water runoff from areas considered to be from various "Nonpoint Source" Sources shouldn't the controls/considerations identified in Section 9.2 also be listed as control/reduction strategies for MS4 loadings?

11. The data reported in Appendix E demonstrate that the great majority of samples seem to have animal, rather than human, origins, and many of the samples suggest that wild animals are a primary part of the problem. Much of the area is wooded or covered with heavy brush, and solutions to this problem may be difficult to find.

Reporting errors

12. On page 23, the numbers in Table 9 are incorrect. They are taken from Table B-2 on page B-10, but in Table B-2, the names of McCrory Creek and Stoners Creek are reversed. Table B-2 shows a FC density of 259.9 for Stoners Creek, but the monitoring data on the bottom of page B-7 shows that the highest 10-sample average for Stoners Creek was 71.6. The 259.9 value was for McCrory Creek[3].

13. As a result of the error in comment 12, the percent reductions for both Stoners Creek and McCrory Creek are incorrect[4]. Stoners Creek did not violate the 10-sample maximum or the simulated 30-day average. The highest simulated 30-day average was 104.1 (or 100 CFU/100 mL). The only violation of any standard on Stoners Creek during the previous 5 years[5] was the count of 2900 CFU/100 mL, on August 10, 2000, and this was due to a pump failure at the Dodson Chapel Pumping Station. We do not believe that there is a consistent FC problem on Stoners Creek that requires steps to achieve any specific percent reduction. We believe that the recent data show that Metro needs only to take one step to achieve compliance with the water quality standard: prevent future pumping station bypasses.

14. On page B-10, as noted earlier, the names of McCrory Creek and Stoners Creek are reversed in Table B-2. Load reduction figures are thus incorrect. Also, the value of 181.3 is not 6% greater than 180; it is 0.7% greater, although we would consider these two values equivalent. (See footnote 1.)

Dynamic Loading Model

15. On page B-1, the appendix is labeled "Appendix D" instead of "Appendix B".

16. Can the "Fecal Coliform Loading Estimation Spreadsheet" (FCLES) referred to in B.2. be made available to the public for consideration?

3 Based on recommendations in *Standard Methods*, bacterial densities should be reported with two or fewer significant figures. This reflects the uncertainty and variability in these types of tests. Thus, a geometric mean FC density of 259.9 CFU/100 mL should be reported as 260 CFU/100 mL.

4 Using 3 or more significant figures in the required percent reduction implies a greater degree of precision than actually exists. We believe that a 50% reduction is as meaningful as a 51.3% reduction.

5 According to EPA, "As much as possible, managers should identify the problem based on currently available information, including water quality monitoring data…" (Protocol for Developing Pathogen TMDLs, (first ed.) Office of Water U.S. Environmental Protection Agency, Washington DC, EPA 841-R-00-002). Only data collected within the past 5 years should be used when constructing TMDLs, and thus the data for McCrory Creek and Stoners Creeks reported in September 1996 should not be included in the development of this TMDL. We believe that the required load reduction for McCrory Creek should be based solely on the violation of the 10-sample maximum, and therefore that the required load reduction for McCrory Creek is 30% (30.7%)

17. On page B-3, section B.3, many details are provided regarding the calibration of the LSPC model, including in-stream FC decay rates, rate of accumulation of FC, maximum storage of FC, rate of surface runoff that

will remove 90% of stored FC bacteria, etc. The following sentences, found in section B.3.2 and B.3.2.2.5 suggests that variable values were altered from their initial values in order to calibrate the model:

> *Model variables were adjusted, within reasonable limits, until acceptable agreement was achieved between simulated and in-stream observed data was achieved [sic].* (page B-4)

and,

> *Flow and concentration variables were adjusted during water quality calibration to best fit simulated in-stream fecal coliform concentrations during dry weather conditions.* (page B-6)

It would be beneficial to the reader to know both the initial parameter value and the value ultimately used in the simulation.

18. Did area dam release flow values impact the modeling calibration for these two segments?

19. On page B-4, it is reported that the assumed deer population was twice the state average, or 45 animals per square mile (B.3.2.2.1.) This seems extremely conservative. It might be above average in some of the areas of the basin, but not all. Too much of the area is too highly developed.

20. Is "Horner, 1992" (found in B.3.2.2.4) currently considered by EPA to be the most reliable data available for this type of model use/TMDL formulation?

21. On page B-4, it is noted that "Only a portion of the load from these sources is actually delivered to the streams due to the mechanisms of wash off (efficiency), decay, and incorporation into soil (adsorption, absorption, filtering) before being transported to the stream." We agree. However, on page 22 it was stated that "fecal coliform applied to land surfaces was not subjected to die-off or adsorption rates…" In addition, section B.5.1. seems to indicate that 100% of deposited FC loading is considered to wash into receiving streams. However, some degree of UV degradation and/or decay of land-deposited FC bacteria will occur during dry periods. These statements appear to conflict. Please explain.

22. The Dynamic Loading Model method for Stoners Creek determined that no reduction percentage for FC was required. How would TDEC handle a situation where all modeling methods/considerations for a 303(d)-listed segment came back as requiring no reduction for the impacting pollutant?

<u>Flow Duration Curve</u>

23. Some of the sample densities in Table C-1 and C-2 are not found in tables in Appendix A, which lists sampling data. It should be pointed out explicitly in the tables that these values are geometric means of multiple samples taken on a given day.

24. We have strong reservations about using average daily flow data in the construction of Load Duration Curves for urban streams. Urban streams, unlike larger established rivers or rural streams with ample watershed storage are very flashy, and thus average daily flows do not always capture the variable hydrodynamics (and resulting variable runoff behavior) over the course of a wet-weather day. In fact, Bonta and Cleland (2003) note:

> Flow duration curves are characterized by the time base of the data used in their development. Given the same watershed flow data, FDCs developed from minutely, daily, weekly, etc., data will have different characteristics (Searcy, 1959). This is apparent, for example, from FDCs developed using average daily flow data that do not account for the variation of runoff rate changes throughout the day (Figure 3). This assumption may be adequate for large river basins where flow rates change gradually. However, *average daily flow rates do not capture the potentially large variability of watershed runoff observed in small watersheds over a single day* [emphasis added].[6]

Likewise, the seasonal variation in base flows experienced in these urban streams adds additional uncertainty to this approach. Base flows (i.e., dry weather flows) vary in tributary streams in Davidson county from mere cubic feet per second (cfs) in the late summer and fall months to values approaching 100 cfs in the winter and spring. The variability in seasonal base flow rates makes comparison with average daily flow rates (which may be influenced by short-term wet weather episodes) over a year-long period difficult, if not intractable. At the very least, some effort should be made to show that developing load duration curves with average daily flow rates for flashy and seasonally variable urban streams is equivalent to using methods that use instantaneous data and address seasonal variability.

<u>Proposed future steps</u>

In response to the placement of McCrory Creek and Stoners Creek on the section 303(d) list and production of this TMDL Report, Metro intends to continue its efforts to identify and eliminate or reduce pollutant sources in these basins. On McCrory Creek, the following steps will be taken:

1. Metro will continue to work to reduce infiltration and inflow (I/I) into the sewer lines that lead to the McCrory Creek Pumping Station in order to eliminate bypasses;
2. Vanderbilt University (VU) will continue to monitor the creek at several locations on a quarterly basis;
3. Any samples that produce *E coli* densities in excess of 470 EC/100 mL (50% of the single sample maximum) will be re-sampled and VU will conduct antibiotic resistance analysis (ARA) to determine the likely source of the *E. coli*;
4. VU will conduct two intensive (5-times-per-month *E. coli*) monitoring events during the recreation season in order to determine if the stream now meets state water quality criteria.

On Stoners Creek, the following steps will be taken:

1. Metro will continue to work to reduce I/I into the sewer lines that lead to the Dotson Chapel Pumping Station in order to eliminate bypasses;
2. VU will continue to monitor the creek at several locations on a quarterly basis;
3. Any samples that produce *E. coli* densities in excess of 470 EC/100 mL will be resampled and VU will conduct ARA to determine the likely source of the *E. coli*.

6 Bonta, J. V. and Cleland, B. 2003. Incorporating natural variability, uncertainty, and risk into water quality evaluations using duration curves. *Journal of the American Water Resources Association*, 39: 1481-1496.

APPENDIX H

Response to Public Comments

Response to Metro Water Services Comments

1. The State of Tennessee's final 2002 303(d) list was approved by the U.S. Environmental Protection Agency (EPA), Region IV in January, 2004. The list identified segments of McCrory Creek and Stoners Creek as not fully supporting designated use classifications due to pathogens. The 2002 303(d) list was based on the latest data and assessment information available at the time that it was developed. Table 4 in the TMDL document summarizes this assessment information.

   Metro Water Services (MWS) submitted comments on the draft 2002 303(d) list to the Division of Water Pollution Control (DWPC) via a letter (with attachment) dated September 9, 2002. The data provided in support of the comments included much of the data referenced in the TMDL document. In the comments, MWS agreed with the Stoners Creek listing and recommended that the McCrory Creek listing be modified to include only the lower portion of the creek as impaired due to pathogens. DWPC agreed with this recommendation and the final 303(d) list, approved by EPA, identified only the lower 1.4 miles as impaired due to pathogens.

2. DWPC would consider using a conversion factor to estimate E. coli bacteria from fecal coliform data if it were based on site specific data that were representative dry and wet conditions over a period of several years. Use of the conversion factor developed in Comment #2 would result in required load reductions, using the load reduction curve methodology, of 66.0% for Stoners Creek (compared to 68.9% for fecal coliform) and 46.8% for McCrory Creek (compared to 51.3% for fecal coliform). This does not appear to be significant for this type of analysis.

3. TMDL analyses were performed on the drainage areas of both McCrory Creek and Stoners Creek upstream of the segments identified as impaired due to pathogens. Waste Load Allocations (WLAs) and Load Allocations (LAs) apply to the entire drainage areas. A reasonable implementation strategy would be to concentrate load reduction efforts in the vicinity of the impaired segments and evaluate the resulting effects on water quality. If the desired improvements are not achieved in a reasonable time frame, expand the scope of load reduction measures to the entire drainage areas. The overall goal is the restoration of water quality in the listed waterbody segments.

4. The DWPC agrees that primary causes of pathogen impairment in McCrory Creek and Stoners Creek are identified sanitary sewer overflows (SSOs). Elimination of SSOs through the Metro Nashville/Davidson County Overflow Abatement Program is cited as a primary TMDL implementation strategy (ref: Section 9.1.1).

5. Both implicit and explicit MOS have been used in the majority of pathogen TMDLs proposed by DWPC, including those for the South Fork Forked Deer, North Fork Forked Deer, Loosahatchie, Nonconnah, Fort Loudon Lake, Hiwassee, Lower Elk, and Wolf River watersheds. The DWPC considers the use of implicit and explicit MOS to be appropriate in consideration of the uncertainties in the analysis methodologies used and the data available.

6. All available data is considered for use in a TMDL. Emphasis is normally given to more recent data, but older data is frequently used for model water quality calibration and trend analysis. Since the TMDL addresses impaired waterbodies on the 1998 303(d) list, 1996 data was included in the document as relevant to that listing.

7. The *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* and the *Class II Concentrated Animal Feeding Operation General Permit* are the general permits that are relevant to pathogen loading. Small MS4s and CAFOs covered under these general permits were considered as loading sources in TMDL development (ref: Sections 7.1.2 & 7.1.3).

8. Discharges from MS4s are considered to be the responsibility of the MS4 permittee, whatever the source. Source identification methodologies would undoubtedly be useful to MS4s in the development and implementation of measures to reduce pathogens in their discharge. Cooperation among stakeholders (both point and nonpoint sources) in the development of watershed-wide BMPs will be needed for implementation of WLAs and LAs. Follow up monitoring and assessment activities will be required to evaluate the effectiveness of pollution reduction actions.

9. In Section 9.1.3, it is stated that WLAs for MS4s will be implemented through Phase I & II MS4 permits. The information cited on pages 25 & 26 is intended to serve as a brief, general statement of the Metro Nashville/Davidson County MS4 permit requirements with respect to the Storm Water Management Program (SWMP) and required pollution reduction measures. A summary of these requirements should not be "confusing or distracting" to the permittee.

10. Some of the controls/considerations in Section 9.2 could also be relevant to MS4s.

11. Comment noted.

12. The proposed Stones River fecal coliform TMDL was placed on Public Notice for 35 days on March 8, 2004. Several typographical errors were brought to the attention of the DWPC at a meeting with Metro Water Services (MWS) to discuss the proposed TMDL on March 12. These errors were corrected in the TMDL document on March 15 and the comment period extended 10 additional days. Letters were sent to a number of stakeholders advising them of the corrected document.

13. See response to Comment 12.

14. See response to Comment 12.

15. See response to Comment 12.

16. The Fecal Coliform Loading Estimation Spreadsheet (FCLES) will be made available to anyone that requests it.

17. There are a large number of variables in LSPC (based on HSPF) that potentially affect simulated flow and fecal coliform concentration. Variables in each segment can vary according to land use and some variables also vary monthly. The variables that are typically adjusted for hydrologic and water quality calibration are summarized below. A copy of the hydrologic and water quality calibration input files for the Stoners Creek, McCrory Creek, and Christmas Creek models can be provided on request.

LSPC Model Variables Typically Adjusted During Calibration

Calibration Type	Variable	Description
Hydrologic	LZSN	Lower zone nominal storage
	INFILT	Index to infiltration capacity of the soil
	LSUR	Length of assumed overland flow plane
	SLSUR	Slope of the overland flow plane
	KVARY	Parameter which affects the behavior of groundwater recession flow, enabling it to be non-exponential in its decay with time
	AGWRC	Basic groundwater recession rate
	INFEXP	Exponent in the infiltration equation
	INFILD	Ratio between the max and mean infiltration capacities over the pervious land segment
	DEEPFR	Fraction of groundwater inflow which will enter deep (inactive) groundwater and be lost
	BASETP	Fraction of remaining potential evapotranspiration which can be satisfied from baseflow (groundwater outflow)
	AGWETP	Fraction of remaining potential evapotranspiration which can be satisfied from active groundwater storage if enough is available
	UZSN	Upper zone nominal storage
	NSUR	Manning's n for the assumed overland flow plane
	INTFW	Interflow inflow
	IRC	Interflow recession parameter
	MON-INTERCEP (CEPSCM)	Interception storage capacity at start of each month
	MON-LZETPARM (LZETPM)	Lower zone evapotranspiration parameter
Water Quality	ACQOP	Rate of fecal coliform accumulation bacteria
	SQOLIM	Maximum storage of fecal coliform bacteria
	WSQOP	Rate of surface runoff which will remove 90% of stored fecal coliform bacteria per hour
	IOQC	Concentration of fecal coliform bacteria in interflow outflow
	AOQC	Concentration of fecal coliform bacteria in groundwater outflow
	FSTDEC	First order decay rate

18. As stated in Section B.3.1 of Appendix B, LSPC hydrologic calibration was based on the USGS continuous record station located in Stoners Creek near Hermitage, Tennessee (USGS 03430147). Releases from Percy Priest Dam were not a factor in the calibration.

19. As stated in Section B.3.2.2.1 of Appendix B:

> The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes.

    The use of 45 animals per square mile was used to account loading from all other wildlife and is only a component of the FCLES calculation for use as initial input for model pollutant loading variables. Initial model input variables were adjusted "within reasonable limits until reasonable limits until acceptable agreement was achieved between simulated and instream observed data was achieved." Model water quality calibration was discussed in Section B.2.

20. Data from Horner was used by Tetra Tech, a consultant to EPA, in the development of the FCLES spreadsheet. This tool was distributed by EPA to states in Region IV for TMDL development. The Horner data was also used in the FCLES spreadsheet as a component of the initial input for model pollutant loading variables. As stated in the response to Comment 19, model variables were adjusted as required during water quality calibration.

21. In the model, die-off of fecal coliform bacteria deposited on land surfaces is not directly considered. There is a model variable, however, that limits the amount of fecal coliform accumulation. The net effect of both die-off and limiting accumulation is that there are fewer bacteria available for washoff during storm events than would otherwise be the case. In order not to be misleading the statement on page 22 was removed.

22. If all analyses indicated that no reduction in pollutant loading was required, possible actions by DWPC include: reassessment of the impaired waterbody, collection of additional data under a wider range of flow and loading conditions, development of a more detailed model, or use of an alternative analysis method.

23. It is stated in Appendix C, Section C.2, #3 that on days where multiple samples were collected, the geometric mean of the sample values was used. In order to avoid confusion, footnotes have been added to Tables C-1 & C-2.

24. Load duration curves developed from minutely flow will undoubtedly be more "accurate" than load duration curves developed from daily mean flows with respect to capturing the potentially large variability of watershed runoff observed in small watersheds over a single day. The runoff data used in the paper cited were from the 40-year instantaneous flow records from the 21.4 ha experimental Watershed 174 located at the North Appalachian Experimental Watershed (NAEW) near Coshocton, Ohio. Instantaneous flow data that are continuous over a long period of time, however, are not generally available for TMDL development.

    The load duration curves developed for the TMDLs were based on over 11 years of daily mean data from a USGS continuous record station in Stoners Creek and were considered to be representative of the range flows occurring at that station. Any error due to the use of daily mean data rather than instantaneous data argues for increased MOS. In any case, when adequate instantaneous data is made available, the TMDLs can be refined to reflect the new data.